Progress Report 181

Oil and Gas Developments in Pennsylvania in 1969 with Ten Year Review and Forecast

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ABSTRACT

Oil and gas activities in Pennsylvania in 1969 were highlighted by a number of significant developments. Well completions in excess of 50 BOPD and/or 2 MMCFGPD increased in number from 1968, 30 to 72, and in percent of total wells drilled, 4 to 7 percent. The extensive west-central Pennsylvania Upper Devonian pre-Speechley gas development drilling reported last year increased by 87 percent during 1969 and has expanded in area on trend. Northwestern Pennsylvania Upper Devonian Glade Sandstone development, with 22 percent highlight well completions, continued during 1969. Development drilling in and about old Venango Sandstone fields continued to result in a number of completions in excess of 50 BOPD. A significant Murrysville Sandstone gas discovery with reported potential of 6.3 MMCFGPD was made in Westmoreland County.

During 1969, drilling and production of oil increased 16 and 7 percent respectively. Pennsylvania Grade oil production was 4,403,000 Bbls. Pennsylvania Grade oil reserves declined 7 percent to 59,188,000 Bbls. Production (79,134 MMCF) and reserves (1,303,907 MMCF) of gas declined during the year, 10 and 3 percent respectively as drilling for gas increased 8 percent. Service (including secondary recovery), storage, stratigraphic, and other miscellaneous wells increased 9 percent in 1969. Of the 895 primary wells drilled and/or completed, 42 were exploratory and 853 were development wells. This represents a 31 percent decline in wildcatting, and a 16 percent rise in exploitation. Successful completions accounted for 31 percent of the exploratory and 95 percent of development wells. Only 25 deep wells were drilled or completed, 9 of which were exploratory and resulted in 3 gas discoveries. There were 14 deep gas development wells, and 2 dry holes. Of the 870 shallow primary wells, only 33 were exploratory and resulted in 2 gas and 2 oil discoveries. Successful oil completions accounted for 65 percent, and gas completions 30 percent, of shallow development. Exploratory and development drilling footage increased 5 and 7 percent respectively.

Primary industry activity was concentrated in known and historic formations and areas.

Although gas storage capacity remained approximately the same, stored gas rose 2 percent to 498,569 MMCF. A number of subsurface disposal projects were under consideration by various industries during the year. One disposal well was drilled. Completion is pending during evaluation and testing. Secondary and tertiary recovery activity appeared to increase during the year although indications of profitable results of non-experimental projects to date appear to be limited.

A ten year review and forecast indicates a gradual decline of shallow oil reserves, continued development of shallow gas, and a number of excellent prospects for discovery of significant gas reserves in presently unevaluated deep horizons. Delayed expansion of new horizon developments in surrounding states into Pennsylvania is a pattern related to conservative exploitation of the known and cautious probing of the unknown.

INTRODUCTION

The new format for reporting of oil and gas industry activities in the Commonwealth was initiated last year with Progress Report 177, *Oil and gas developments in Pennsylvania in 1968.* Reference is made to Progress Report 178, *Representative gamma-ray logs from shallow and deep wells, western Pennsylvania,* which contains three shallow gamma-ray logs (two from the oil belt and one from the gas fields), and one deep gamma-ray log on which shallow and deep producing intervals have been designated. These logs supersede the generalized stratigraphic columns formerly presented in the annual oil and gas development reports and can be ordered separately.

The change in format was initiated to emphasize that good completions regularly are made in the State, and that the large number of poor or stripper completions and long productive history of Pennsylvania in no way preclude the excellent potential for significant reserves of oil and gas in old as well as new horizons. Low cost operations on fee or long-term leased land with limited application of geological and technological advances is mostly responsible for the excessive number of marginally productive completions. The first part of this annual report draws attention to good 1969 completions or highlight wells. Part II contains the statistics and review of industry activities for the year and Part III is the summarized records of 1969 deep wells.

The close of 1969 marks the end of one decade and the beginning of another. This year's report contains a ten year review and forecast (Part IV) in which long-term industry results and trends are summarized.

Even more than industry highlights, the trends and outlook for Pennsylvania emphasize excellent long-term prospects for the discovery of significant new hydrocarbon reserves, particularly gas.

ACKNOWLEDGMENTS

The cooperation of the Bradford District Producers Association has been extremely helpful. Appreciation is extended to the Pennsylvania Department of Mines and Mineral Industries whose Oil and Gas Division has furnished and shared oil and gas drilling data. The Department of Commerce, Department of Forests and Waters, and the Pennsylvania Game Commission have also been helpful by supplying and sharing new data. Reserve information from the American Petroleum Institute and the American Gas Institute is gratefully received. Appreciation is extended to operators and companies who released data pertinent to highlight well completions.

PART I. COMPLETION HIGHLIGHTS FOR 1969

SHALLOW HIGHLIGHTS

As established in Progress Report 177, the lower limits used in considering a shallow well (Upper Devonian or Mississippian) as a highlight well are an initial potential over 50 BOPD and/or over 2 MMCFGPD.

Number of Highlight Wells Increase in 1969

Accompanying an overall increase in drilling during 1969, 72 shallow highlight wells were reported, an increase of 42 wells over 1968. Significantly, the highlight wells rose from four percent of the total in 1968 to seven percent in 1969. Table 1 gives highlight well statistics.

Table 1. Highlight well statistics.

	1969			1968		
Fields with Highlight wells	20			17		
Counties with Highlight wells	8			9		
		Gas	*Oil*		*Gas*	*Oil*
Pre-Speechley wells (Zone B) *	26	19	7	15	11	4
Speechley wells (Zone B) *	37	0	37	11	1	10
Pink Rock (Zone C) *	1	1	0	0	0	0
Zone D* and Mississippian rocks	8	0	8	4	0	4
Totals	72	20	52	30	12	18

* Zones of Upper Devonian rock established in Progress Report 178.

The percent increase in highlight wells may reflect a small improvement in selectivity for optimum reservoir development and greater utilization of modern completion techniques. As discussed in Progress Report 177, widespread stripper-well operational methods by many operators with limited application of modern geological, geophysical, and engineering technology masks the potential of the Commonwealth for highly profitable completions. It is the highlight wells that evidence this potential. Despite the relatively small percentage of highlight wells being completed, it is apparent that more geological and geophysical evaluation should more clearly delineate areas of maximum reservoir development, decrease random drilling or deepening which largely accounts for the number of stripper wells, and greatly improve the percentage of highlight well completions.

Figure 1 shows the distribution of the shallow highlight wells. The following is a brief description of those highlight occurrences about which information was released. Unfortunately, data beyond that submitted for Department of Mines and Mineral Industries well records could not be acquired for some highlight wells and areas not discussed further.

Greatly Expanded Pre-Speechley Gas Play in West-Central Pennsylvania

Exploration for deeper (3000 to 4000 feet) Upper Devonian Zone B gas in west-central Pennsylvania, previously highlighted in Progress Report 177 for 1968, increased 87 percent in 1969 (142 to 265 wells completed). As anticipated, this play has expanded along trend into new areas, particularly to the south in Westmoreland County. The 19 highlight completions account for 7 percent of the wells drilled for this objective. The following tabulation indicates the number and volume of initial completions reported for the various counties encompassing this play. These data are tabulated from reports by Petroleum Information and may not correspond with figures in Part II of this report which are based on data from Department of Mines and Mineral Industries.

Table 2. Initial volumes of wells drilled in pre-Speechley play.

County	*Dry Holes*	*< 1 MMcf*	*1-1.9 MMcf*	*> 2 MMcf*	*Total*
Armstrong	8	29	3	1	41
Clearfield	0	7	1	0	8
Indiana	8	86	46	9	149
Jefferson	4	27	11	8	50
Westmoreland	2	6	8	1	17
Total	22	155	69	19	265

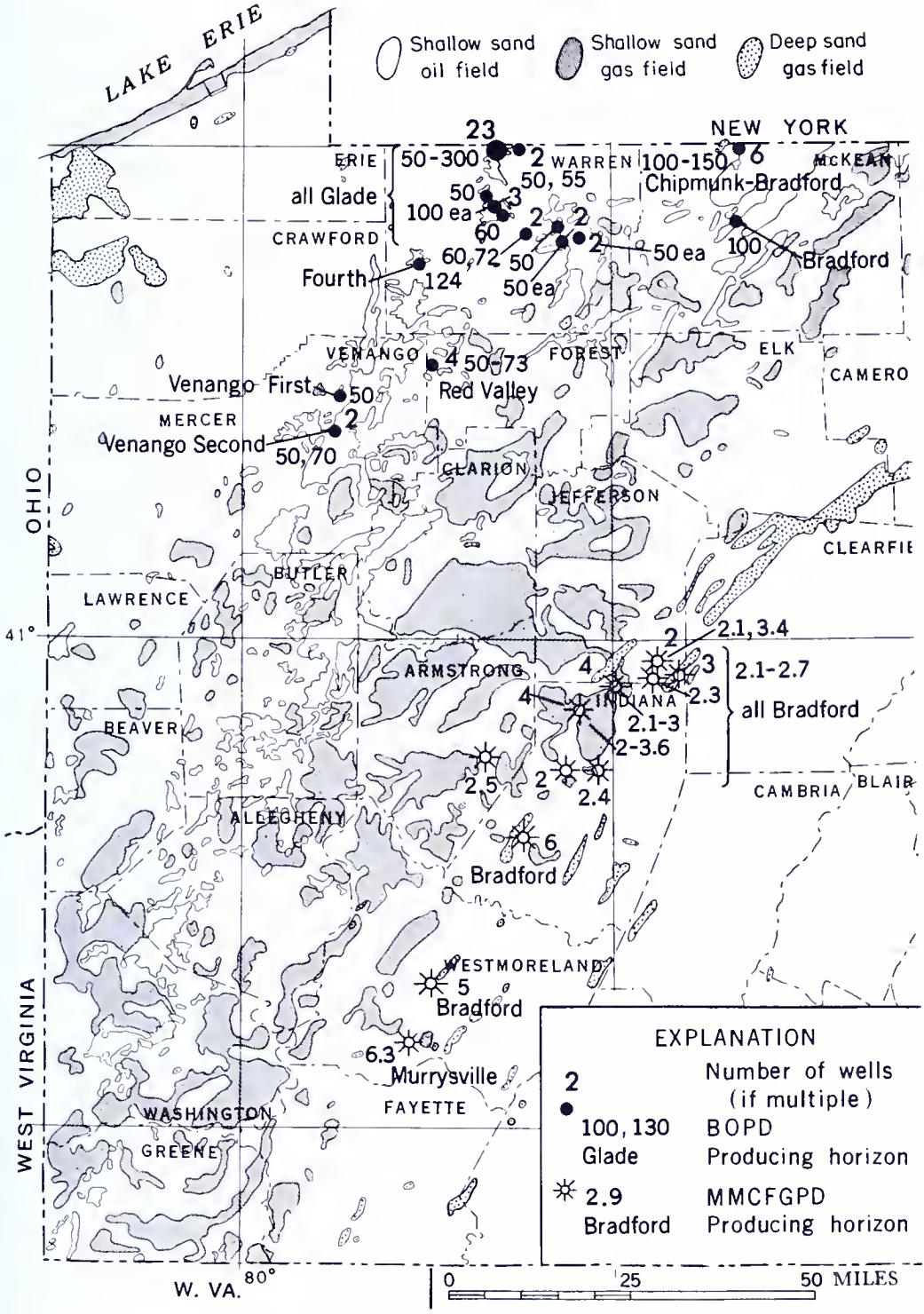


Figure 1. Highlight wells reported in 1969

Production is obtained from at least five separate sandstone zones, locally designated Balltown, Sheffield, Bradford, and Kane sandstones (illustrated in Progress Report 177). In most cases these zones are stratigraphically lower than sandstones of the same name in the older oil producing areas to the north. Highlight wells are generally located in trends of optimum reservoir sandstone development in one or more of these zones. Development of these new deeper Upper Devonian reservoirs is expected to continue into areas that are essentially unevaluated both to the northeast and southwest on trend, extending known shallow gas fields to the east above the area of deep Oriskany fields and structural trends along the eastern edge of the Plateau.

Glade Sandstone Oil Development Continuing During Year

Development of oil production from the Glade and related (Clarendon, Gartland) sandstones (Zone B), has continued during 1969 in and about old Glade fields in north-central Warren County. During 1969, 171 wells were drilled, of which 1 was a dry hole and 37 reported highlight initial pumping completions of 50 BOPD or more (22 percent). This shallow, 600 foot deep sandstone play was described and illustrated in Progress Report 177. Continued Glade development with accompanying highlight completions in well-developed reservoir sandstone is anticipated during 1970, although at a slower pace than in 1969.

Completions in Old Venango Sanstone Fields Continue to Produce Highlight Oil Wells

A total of 126 wells, including 5 dry holes, were drilled for Venango sandstone oil production (Zone D) in Venango and Forest Counties. Individual well potentials for many common tank battery completions are unreported, and consequently the proportion of highlight wells for this interval cannot be ascertained. One highlight well was reported from the Venango First sandstone. The Tarr #62 Fee in the old Oakland field, Section G, Titusville Quadrangle, Venango County, was completed on August 9, 1969 for an initial pumping potential of 50 BOPD after hydrofracture treatment of perforations between 606-623 feet.

Two additional highlight wells from the Venango Second sandstone were reported by Quaker State Oil Corporation in the old Foster Reno field of Venango County in 1969, one with initial pumping potential (IPP) of 50 BOPD (#21Q Upper Reno) and the other with IPP of 70 BOPD (#19Q Upper Reno). Venango Second sandstone highlight wells in this field at depths of approximately 500 feet were described and illustrated in Progress Report 177.

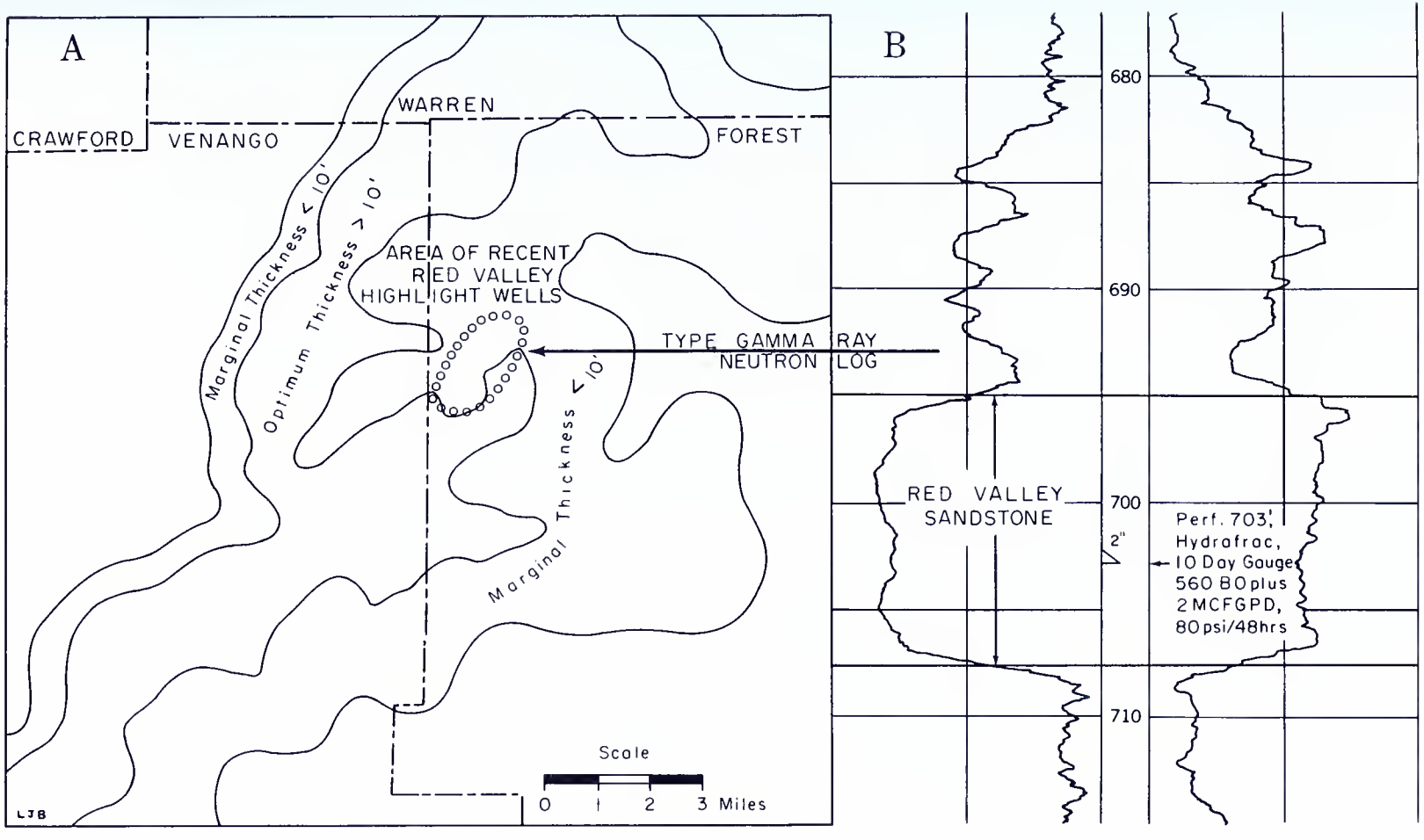


Figure 2. Red Valley sandstone, Venango and Forest Counties, Pennsylvania.

A. Isopach map of 80 percent gamma ray clean sandstone.

B. Gamma ray-neutron log of highlight well from area of recent Red Valley drilling.

Four of the seven Venango sandstone highlight wells were completed in the Red Valley sandstone of extreme western Forest County and along the eastern edge of reservoir sandstone development in this beach bar deposit (Figure 2). The section is thin, but locally porous. Eleven wells in the old White Church field were reported in 1969, 3 of which were drilled in late 1968. The average IPP per well is 39 BOPD after 10 days. Depth is 600-700 feet, with completed costs for new wells averaging $9 to $10 per foot. Two-inch tubing is hung opposite the pay in open hole. The sandstone is hydrofraced through selected perforations. Approximately four of the wells reported this year, and many of the wells completed recently in the field are either deepened from original total depths in the Venango First sand or plugged back from total depths in the Venango Fourth sandstone.

Although most of the Venango sandstone activity has been concentrated in Forest and Venango Counties, a single highlight well, the Frederick #7 Gates, was reported in southwestern Warren County. This well was completed on October 1, 1969 from perforations at 621-622 feet in the Fourth sandstone (lower portion of the Venango Third interval) for an IPP of 124 BOPD and some water through two-inch tubing hung in open hole opposite the sandstone.

Continued development of Pennsylvania's shallow oil with a steadily improving proportion of highlight wells signifies new reserves in the many old shallow fields and stimulates interest in recovery of the oil still left in the ground.

Murrysville Discovery Highlights Pennsylvania's New Shallow Gas Potential East of Extensive Old Gas Fields

On August 21, 1969 Snee-Eberly-Peoples completed their #1 Evans, a 2,183 foot Westmoreland County shallow wildcat from the Murrysville for 6.3 MMCFGPD natural, from open hole below 7 inch casing at 1,750 feet. Gas was reported at 2,182 feet and because of the volume geophysical logs could not be taken. Figure 3 shows the location of the Sherrick Run Pool discovery and a geophysical log cross section illustrating the stratigraphic position of the new pay and the variation in multiple reservoirs of the uppermost Devonian and Lower Mississippian sandstones of this area. Scattered shallow fields and pools in this portion of Pennsylvania produce primarily from deeper "Bayard" sandstones (Zone C) and Zone B sandstones.

This significant discovery further emphasizes the gas potential of Upper Devonian reservoirs in the many essentially unevaluated areas to the east of extensive old shallow fields and above deep Oriskany fields and structural trends along the eastern edge of the Plateau.

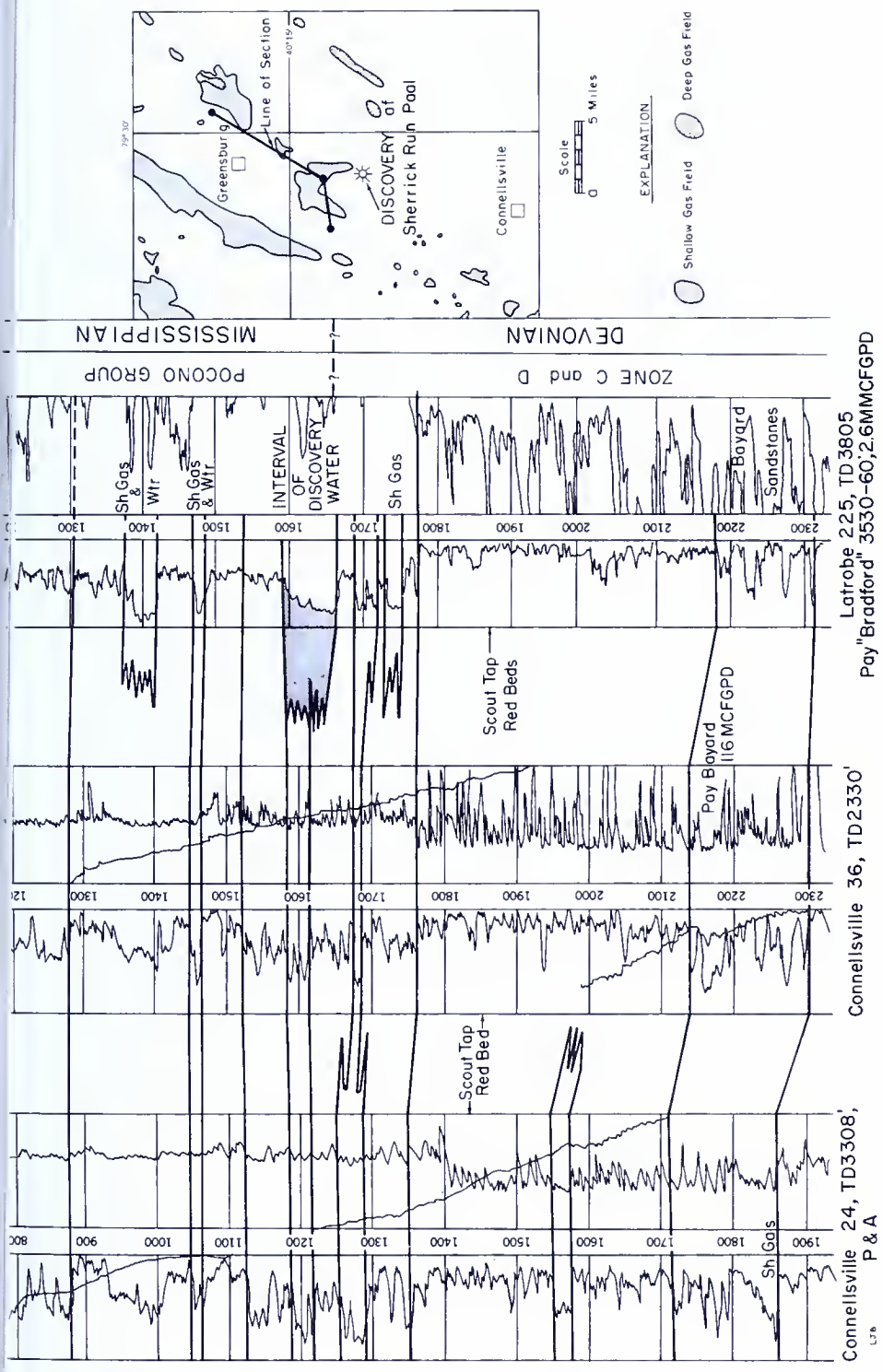


Figure 3. Variations in Upper Devonian (Zone C and D) sandstone reservoirs and Mississippian Murrysville sandstone discovery well.

DEEP HIGHLIGHTS

The lower limit used in considering a deep formation completion as a highlight was established in Progress Report 177 as 10 MMCFGPD. During 1969 there were no deep highlight wells.

PART II. OIL AND GAS INDUSTRY ACTIVITY FOR 1969

BENEFIT OF WELL DATA AND BASIS FOR STATISTICS

Reliable subsurface oil and gas well data are necessary for expansion and promotion of the oil and gas industry, as well as other subsurface appraisals. Such data are also necessary for effective evaluation of subsurface storage or disposal potenial, subjects of increasing interest in Pennsylvania. The development of brine production, fresh water zones, and industrial mineral zones also requires reliable subsurface data.

Because local oil and gas companies and operators can benefit from an expanding oil and gas industry as well as from comprehensive subsurface evaluation, it is in their own best interest to promptly report accurate well data. Delaying reporting of data results in a mistaken impression of current oil and gas development activity. Incomplete or inaccurate reporting results in erroneous interpretations or evaluations of subsurface potentials.

Meaningful benefits will accrue to the producers and developers in Pennsylvania, to the economic well being of the Commonwealth, and to the national oil and gas industry when prompt, accurate, and complete well data are reported.

Local industry statistics herein reported are consistent with figures submitted to national industry organizations. Consequently, drilling and completion data are entirely based on drillers' records and location plats forwarded to the Pennsylvania Geological Survey by the Department of Mines and Mineral Industries, Oil and Gas Division, the administrative and regulatory agency for the Oil and Gas Laws. Only those wells for which records and plats have been received within the year are reported. This includes wells drilled in prior years for which records were submitted and received in 1969. It does not include 1969 wells completed for which records had not been submitted within the year to the Department of Mines and Mineral Industries. The following Table 3 indicates the extent to which the figures reported actually represent activity within the year for the past ten years.

Oil production and reserves data were obtained from the American Petroleum Institute, gas production and reserves data were obtained from the American Gas Institute and data on county production and producing wells (Table 4) were obtained from the Pennsylvania Department of Commerce, Bureau of Statistics.

Table 3. Percent comparison of wells drilled during year to wells reported during year.

Year	*Reported in year Drilled/Completed in Previous Years*	*Drilled/Completed in Year, Reported in Subsequent Years*	*Drilled/Completed in Year, Reported in Year*
1960	29	24	76
1961	27	21	79
1962	30	24	76
1963	20	35	65
1964	31	30	70
1965	35	43	57
1966	30	36	64
1967	39	37	63
1968	43	23	77
1969	27	(0)	(100)
Average	31 (Excluding 1968-1969)	31 (Excluding 1968-1969)	69

*Table 4. Oil wells and crude oil in Pennsylvania by counties, 1968, 1969**

County	*Number of producing oil wells as of 12/31/68*	*1968 Crude oil production (bbls)*	*Number of producing oil wells as of 12/31/69*	*1969 Crude oil production (bbls)*
Allegheny	240	89,255	236	85,750
Armstrong	85	10,217	84	8,311
Beaver	69	6,410	69	5,904
Butler	1,767	112,882	1,750	117,019
Clarion	423	25,769	413	24,769
Crawford	663	163,058	657	69,285
Elk	69	38,045	65	37,638
Erie	29	1,297	29	601
Fayette	4	294	4	271
Forest	629	63,703	641	65,815
Greene	264	46,119	280	43,846
Jefferson	54	2,690	54	2,373
McKean	15,660	2,301,384	15,207	2,421,345
Mercer	89	925	89	775
Potter	180	16,689	181	18,005
Venango	12,434	314,819	12,132	370,726
Warren	4,996	681,599	5,009	649,977
Washington	730	135,723	725	126,839
Total	38,385	4,010,878	37,625	4,049,249

* Data from the Bureau of Statistics, Department of Commerce, Harrisburg, Pennsylvania.

PREVIOUS COMPILATIONS

The deep well summarized records (those which reach rocks of Middle Devonian age or older) are shown in Table 18 and the location of the deep exploratory wells are on Figure 10. For those deep wells drilled prior to 1950, the summarized records and other information on the Commonwealth's oil and gas activities are to be found in Bulletin M31. Similar information for the 1950 to 1954 period was published in Bulletin M39 and for the 1955 to 1959 period in Bulletin M45. For the years 1960 through 1968 this information was published annually in Progress Reports 158, 160, 165, 166, 168, 172, 173, 175, and 177 of the Pennsylvania Bureau of Topographic and Geologic Survey. Oil and gas developments in the shallow sands (Upper Devonian or younger) are described in Bulletin M45 and Progress Reports 135, 139, 143, 144, 147, 150, 151, 154, 155, 157, 158, 160, 166, 168, 172, 173, 175, and 177.

A list of deep-well samples on file with the Survey was published in the Survey's Catalogue of Deep Well Samples (W. R. Wagner, IC16). Supplemental lists were published in Progress Reports 157, 158, 160, 165, 166, 168, and 173. These and other deep and shallow well samples, geophysical logs, and other well data are also on file with the Survey.

INDICATED STATUS OF LOCAL INDUSTRY

The general status of the local industry is presented by summary comments below. The conclusions drawn will be similar to those nationally derived, inasmuch as they are based on the same reported data and reporting procedures. No attempt is made to define or discuss causes contributing to the trends indicated. Important refining and marketing fluctuations influencing industry activity are beyond the scope of this report and are not reflected by the data available. Consequently, the comments below are restricted to only the end results indicated by drilling and completions reported to the Commonwealth.

Although completed oil wells significantly increased (16 percent), rising production of oil (7 percent) was accompanied by a comparable decline in oil reserves (7 percent). As was the case in 1968, it appears that whether by primary or secondary operations, the local industry is not developing enough oil to supplement or hold reserves steady. Production of oil continues to utilize reserves at a relatively rapid rate.

Reserves of gas declined (3 percent) as did production (10 percent) although completed gas wells increased (8 percent). As for oil, the local industry is not developing enough gas to supplement or hold reserves

steady. However, unlike the oil trend, the decline in reserves accompanies a relatively large decline in gas production. Taking into account a 2 percent increase in gas converted to storage, significantly less gas reserves are being found per well by drilling than in previous years.

Drilling and Completions

Table 5 shows drilling and completions increased during 1969, particularly for shallow oil.

Table 5. Drilling and completions reported 1969.

Classification		*1969*		*1968*		*% Change*
SHALLOW WELLS	New Wells	823		753		+ 9
	Gas	232		225		+ 3
	Oil	539		470		+ 15
	Dry	52		58		- 10
	Deepened	47		26		+ 81
	Gas	26		21		+ 24
	Oil	9		1		+ 800
	Dry	12		4		+ 200
	Sub Total	870		779		+ 12
	Gas	258		246		+ 5
	Oil	548		471		+ 16
	Dry	64		62		+ 3
DEEP WELLS (NEW)	Gas	17		8		+ 110
	Dry	8+		8		0
	Sub Total	25		16		+ 51
PRIMARY SUBTOTAL		895		795		+ 13
	Gas	275		254		+ 8
	Oil	548		471		+ 16
	Dry	72		70		+ 3
Service (Mostly Secondary Oil)		122		101		+ 21
Miscellaneous (Mostly Gas Storage)		15*		25**		- 67
Stratigraphic		1		1		0
OTHER SUBTOTAL		138		127		+ 9
TOTAL ALL WELLS		1033		922		+ 12

* Includes one deep gas storage well drilled deeper.
** Includes one deep well drilled for liquid waste disposal.
+ Includes one deep well which resulted in a shallow discovery.

During 1969 development well drilling increased and exploratory drilling decreased.

Table 6. Exploratory and primary development reported 1969.

Type Well	*1969*		*1968*		*% Change*
Exploratory	42		61		- 31
Gas	10[a]		14		- 29
Oil	3		9		- 67
Dry		29[b]		38	- 24
% Successful	31		38		- 7
Development	853		734		+ 16
Gas	265[c]		240		+ 10
Oil	545		462		+ 18
Dry		43[d]		32	+ 34
% Successful	95		96		- 1
TOTAL	895		795		+ 13
Gas	275		254		+ 8
Oil	548		471		+ 16
Dry		72		70	+ 3
% Successful	92		91		+ 1

[a] Includes 3 deep wildcat discoveries, and 1 deep well completed as a shallow discovery.
[b] Includes 5 deep wildcat failures.
[c] Includes 14 deep wells.
[d] Includes 2 deep wells.

The depth of an average exploratory well increased, although most footage was drilled for shallow objectives at less average depth than in 1968 (Table 7).

Table 7. Footage reported, 1969 and 1968.

	Footage			*Average Per Well*	
Class	*1969*	*1968*	*% Change*	*1969*	*1968*
Exploratory	153,565	146,595	+ 5	3,656	2,528
Development	1,486,239	1,394,375	+ 7	1,742	1,892
Other	291,140	293,161	- 1	2,110	2,308
Total	1,930,944	1,834,131	+ 5	1,869	1,989

The 1969 discoveries are listed in Table 8 and the more important dry exploratory tests are shown in Table 9. The locations of all the exploratory tests are shown in Figure 10. The breakdown of completions

Table 8. Reported discoveries in Pennsylvania, 1969.

Map No.	County	Operator Well No. & Lease	Compl. Date M—D	Basis for Loc.	Total Depth (Ft.)	Name of Formation at TD	Prod. Depth (Ft.)	Prod. Form. or Zone	Initial Daily Prod.	Field or Pool Name	Explor. Class	Remarks
35	Cambria	Kewanee Oil Co. 1 Burley	1/15/69	Sur. and Sub. Geol. Seismic	8,475	Helderberg	8,334	Oriskany	2,100 MCF	Burley Pool	DPD	Laurel Hill Anticline in Patton Field.
36		Peoples Nat. Gas Co. 1 Albert Kubat	6/30/69	Sur. and Sub. Geol. Seismic	8,640	Oriskany	8,581	Oriskany	4,750 MCF	Pindleton Pool	DPD	Laurel Hill Anticline in Patton Field.
23	Clearfield	Cons. Gas Supply Corp. 1 Lee B. Mehrwein	7/17/69	Sur. and Sub. Geol. Seismic	3,240	Canadaway Group	2,676	Canadaway Group	1,463 MCF	Salem Pool	SPD	NW flank of Chestnut Ridge Anticline in Punxsutawney Driftwood Field
38	Fayette	Zenith Exploration Co. 2 Clifford L. Ryan	6/ 3/69	Sur. and Sub. Geol. Seismic	7,950	Oriskany	7,658	Onondaga Chert Oriskany	2,500 MCF	Quebec Run Pool	DPD	Northern end of Preston Anticline in Sandy Creek Field.
2	McKean	Lenco Drilling Co. 1 Stack	11/18/68	Sub. Geol.	880	Canadaway Group	826	Chipmunk	100 BOPD	Stack Pool	SPD	Stratigraphic Trap Bradford Field.
13		Van-Oil Company 2 Studholme	11/22/68	Sub. Geol.	1,858	Canadaway Group	1,800	Cooper	8 BOPD	Crane Run Pool	NPD	Stratigraphic Trap Cooper Field.
31	Westmoreland	Fox, Coen and Sloane 1 George F. Dible	9/12/68	Sur. and Sub. Geol. Seismic	8,250	Helderberg	4,136	Benson	100 MCF	Lyons Run Pool	SPD	Murrysville Anticline in Murrysville Field.
32		Snee, et al. 1 Charles D. Evans	8/21/69	Sur. and Sub. Geol.	2,183	Murrysville	2,183	Murrysville	6,267 MCF	Sherrick Run Pool	NPD	Stratigraphic Trap Latrobe Syncline Armbrust Field.

Table 9. Exploratory failures reported in Pennsylvania, 1969.

Map No.	County	Operator Well No. & Lease	Compl. Date M-Day-Y	Basis for Loc.	Total Depth (Ft.)	Name of Formation at TD	Explor. Class or Field	Remarks
4	Bradford	Pennzoil United, Inc. 1 Dimmig	5/30/69	Sur. and Sub. Geol.	1,570	Canadaway	NFW	Rank wildcat, tested Conneaut & Canadaway pay zones.
25	Butler	Pennzoil United, Inc. P-1 F. W. Heinz	11/14/68	Sur. and Sub. Geol.	3,406	Canadaway	NFW	Tested all Mississippian and Upper Devonian pay zones.
21	Clinton	J. Richmond Assoc., Inc. 1 Milton J. Kelius	8/ 6/67	Sur. and Sub. Geol.	1,813	Conneaut Group	NFW	Rank wildcat, tested some Mississippian and Upper Devonian pay zones.
37	Elk	Sylvania Corp. 3708 Sylvania Corp.	6/ 3/69	Sur. and Sub. Geol. Seismic	7,105	Helderberg	NPW	Oriskany test, southeastern flank of Sabinsville anticline.
14		Pennzoil United, Inc. P-1 Warrant 2612	11/ 2/68	Sur. and Sub. Geol.	4,005	Canadaway	NFW	Tested all pays through Canadaway pay zones.
34	Fayette	Peoples Nat. Gas Co. 1 Pauline Bozek	10/ 2/69	Sur. and Sub. Geol.	5,300	Canadaway	NFW	Tested all pays through Upper Devonian pay zones.
33		Snee & Eberly, et al. 1 A. Merritt	9/ 4/69	Sur. and Sub. Geol.	3,200	Bradford	NFW	Tested all Mississippian and Upper Devonian pay zones.
16	Forest	Pennzoil United, Inc. P-1 Lot 7 Warrant 5189	12/14/68	Sur. and Sub. Geol.	3,750	Canadaway	NFW	Tested all Upper Devonian pay zones.
8	McKean	Pennzoil United, Inc. P-1 Seyler	1/ 4/69	Sur. and Sub. Geol.	2,828	Canadaway	NFW	Tested Canadaway pay zones.
40	Potter	Pennzoil United, Inc. P-1 Cizek	4/ 2/69	Sur. and Sub. Geol.	6,314	Bass Island	NFW	Oriskany test, northwestern flank of Marshlands anticline.
9		Pennzoil United, Inc. P-1 Emporium Lumber Co.	3/22/69	Sur. and Sub. Geol.	3,307	Canadaway	NFW	Tested Canadaway pay zones.
41	Somerset	Peoples Nat. Gas Co. 1 T. D. Barron, et al.	3/15/69	Sur. and Sub. Geol. Seismic	8,780	Helderberg	EXT	Boswell Field extension, Oriskany gas prod. not economical.
3	Tioga	Pennzoil United, Inc. 1 Argetsinger	6/27/69	Sur. and Sub. Geol.	1,502	Canadaway	NFW	Rank wildcat, tested Conneaut and Canadaway pay zones.
10		Pennzoil United, Inc. P-1 Pa. State For. Tr. 150	1/ 3/69	Sur. and Sub. Geol.	3,413	Canadaway	NFW	Rank wildcat, tested all Upper Devonian pay zones.
42	Wyoming	Pennzoil United, Inc. 1 Farr	9/30/69	Sur. and Sub. Geol.	5,385	Tully Limestone	NFW	Rank wildcat, tested all Upper Devonian pay zones.

Table 10. Well completions in Pennsylvania, 1969.*

County	TOTAL		GAS			OIL			DRY	
	No. of Wells	Aver. Total Depth (feet)	No. of Wells	Aver. Init. Open-Flow (MCFGPD)	Aver. Total Depth (feet)	No. of Wells	Aver. Init. Production (BOPD)	Aver. Total Depth (feet)	No. of Wells	Total Aver. Depth (feet)
Allegheny	3	2,412	2	400	2,880	—	—	—	1	1,477
Armstrong	27	3,000	25	314	3,030	—	—	—	2	2,629
Beaver	1	995	—	—	—	1	1	995	—	—
Bradford	1	1,570	—	—	—	—	—	—	1	1,570
Butler	3	2,155	1	20	2,093	1	8	965	1	3,406
Cambria	3	8,543	3	3,517	8,543	—	—	—	—	—
Clarion	11	1,881	5	75	2,272	3	5	1,156	3	1,955
Clearfield	11	3,800	10	523	3,444	—	—	—	1	7,360
Clinton	2	2,518	—	—	—	—	—	—	2	2,518
Crawford	13	4,046	13	1,688	4,046	—	—	—	—	—
Elk	9	2,996	—	—	—	4	41	2,094	5	3,717
Erie	1	1,913	—	—	—	—	—	—	1	1,913
Fayette	7	3,348	2	126	3,768	1	2	3,104	4	3,200
Forest	26	1,336	5	263	1,954	13	22	728	8	1,939
Greene	1	4,717	1	20	4,717	—	—	—	—	—
Indiana	128	3,529	121	1,115	3,528	—	—	—	7	3,559
Jefferson	44	3,443	41	1,600	3,457	—	—	—	3	3,245
McKean	131	1,729	1	2	2,105	125	10	1,708	5	2,186
Mercer	1	5,309	—	—	—	—	—	—	1	5,309
Potter	5	2,407	—	—	—	3	4	1,368	2	3,065
Somerset	1	8,780	—	—	—	—	—	—	1	8,780
Tioga	3	2,387	—	—	—	—	—	—	3	2,387
Venango	156	717	1	2	796	153	9	696	2	2,248
Warren	240	923	—	—	—	234	26	915	6	1,228
Washington	3	3,146	2	—	3,713	1	3	2,012	—	—
Westmoreland	16	3,763	16	1,460	3,763	—	—	—	—	—
Wyoming	1	5,385	—	—	—	—	—	—	1	5,385
TOTAL	848	1,891	249	1,094	3,489	539	17	1,051	60	2,816

* Does not include service wells, miscellaneous wells, stratigraphic/core tests or old wells drilled deeper.

Table 11. Old wells drilled deeper in Pennsylvania, 1969.

County	TOTAL		GAS			OIL			DRY	
	No. of Wells	*Aver. Amt. Deepened (feet)*	*No. of Wells*	*Aver. Init. Open-Flow (MCFGPD)*	*Aver. Amt. Deepened (feet)*	*No. of Wells*	*Aver. Init. Production (BOPD)*	*Aver. Amt. Deepened (feet)*	*No. of Wells*	*Aver. Amt. Deepened (feet)*
Allegheny	1	1,000	1	697	1,000	—	—	—	—	—
Armstrong	10	914	8	67	970	—	—	—	2	692
Butler	1	1,265	—	—	—	—	—	—	1	1,265
Clarion	1	106	1	8	106	—	—	—	—	—
Elk	3	166	—	—	—	—	—	—	3	166
Fayette	1	4,850	1	2,500	4,850	—	—	—	—	—
Forest	9	119	—	—	—	8	19	130	1	35
Greene	1	1,003	1	65	1,003	—	—	—	—	—
Indiana	11	957	10	899	978	—	—	—	1	640
Jefferson	4	252	4	418	252	—	—	—	—	—
McKean	2	337	—	—	—	—	—	—	2	337
Potter	1	3,491	—	—	—	—	—	—	1	3,491
Venango	1	362	—	—	—	1	—	362	—	—
Westmoreland	1	478	—	—	—	—	—	—	1	478
TOTAL	47	755	26	556	981	9	17	156	12	705

by county is shown in Table 10, and the old wells drilled deeper in Table 11. Figure 4 is a graph of the annual rate of shallow well activity in the Commonwealth from 1950 to 1969 while Figure 5 shows the annual rate of deep sand exploration and development from 1930 to 1969.

At the end of 1969 a total of 2,981 deep wells had been drilled in the Commonwealth. Of the 2,981 deep wells, 1,763 were gas wells, 6 were oil and gas wells, 1,073 were dry holes, 135 were drilled for gas storage, and 4 are being used for waste disposal.

Production and Reserves

As shown by Table 12, oil production increased and gas production decreased during the year. Reserves of both oil and gas declined. The portion of gas reserves stored increased slightly.

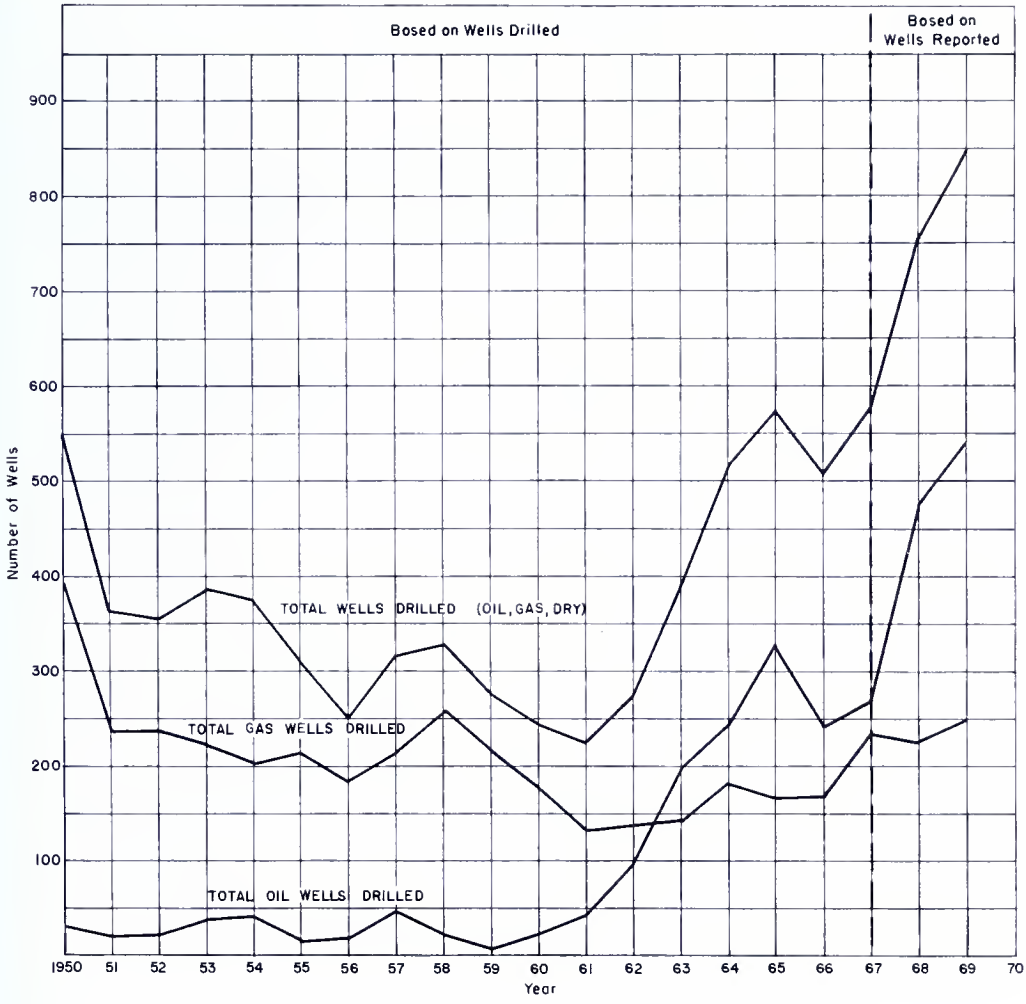


Figure 4. Shallow well activity 1950-1969.

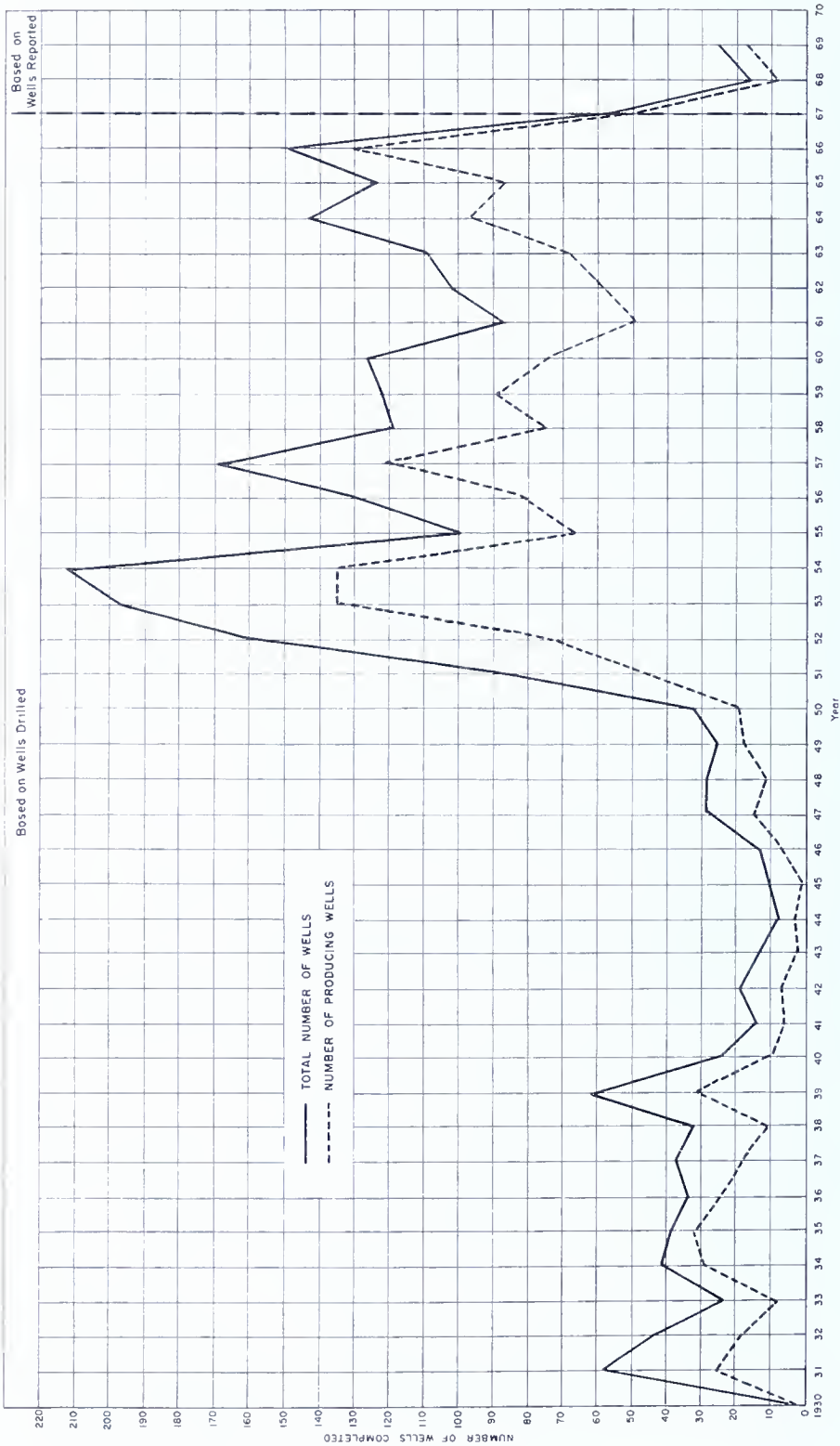


Figure 5. Annual rate of deep sand exploration and development in Pennsylvania.

Table 12. Production and reserves in Pennsylvania, 1969.

		Production				Reserves		
		1969	*1968*	*% Change*	*Cumulative to 12/31/69*	*1969*	*1968*	*% Change*
Oil (1,000 Bbls.)	Pa. Grade	4,403	4,101	+7	1,265,332	54,740	59,188	−7
	Corn. Grade	45	59	−24	142	—	—	—
	Total Oil	4,448	4,160	+7	1,265,474	—	—	—
Natural Gas Liquids (1,000 Bbls.)		90	98	−9	—	974	1,064	−8
(Gas) (MMCF)	Shallow	61,292	62,090	−1	—	—	—	—
	Deep	17,842	25,897	−30	—	—	—	—
	TOTAL GAS	79,134	87,987	−10	8,449,621	1,303,907*	1,344,996*	−3
* Portion Stored Gas						498,569	486,524	+2

The 45,000 barrels of Corning-grade crude oil was produced from the Medina Sandstone (Lower Silurian) in Crawford and Erie counties.

The Bradford District continued to produce the most oil (Table 13).

Table 13. Average Daily Oil Production.

District	*1969*	*1968*	*% Change*
Bradford Field (Pa. portion only)	7,391	6,844	+8
Middle and Southwestern	4,671	4,391	+6
Medina Corning	123	161	−24
TOTAL	12,185	11,396	+7

Figure 6 shows the annual production of crude oil in Pennsylvania from 1859 to 1969 and for the Bradford District from 1871 to 1969. The monthly variation in crude oil price, production and well completions are plotted in Figure 7 for the years 1930 to 1969 for the Bradford District.

The 61,291,611 Mcf of shallow gas had a value of $15,935,818 while the 17,842,489 Mcf of deep gas had a value of $4,906,684. Figure 8 shows the following for the years 1946 to the present: (1) the yearly production of natural gas, (2) the yearly consumption of natural gas, (3) the natural gas reserves and, (4) the amount of natural gas in storage. The deep gas production by field and pool is shown in Table 14.

Gas Storage Fields

There was no reported change in gas storage projects in the Commonwealth during 1969. Storage well activity is carried under the category of "Other" in statistics above (Table 7) and also nationally reported. A decline in storage well drilling and conversion is indicated, although data reported to the State is inadequate to accurately establish storage well and field developments. Storage capacity remained at an estimated 695,543,072 Mcf. Stored gas increased 2 percent to 498,569,000 Mcf (Table 12). Figure 9 shows the distribution and lists the names of known gas storage fields in Pennsylvania. Currently two storage projects are underway, an expansion of the South Beaver Oriskany Pool in Beaver County from 4 to 8 wells with capacity to be close to 3,000 MMCFG and the development of a 1 well Upper Devonian Fifth sand storage pool in Allegheny County. These are included in Figure 9.

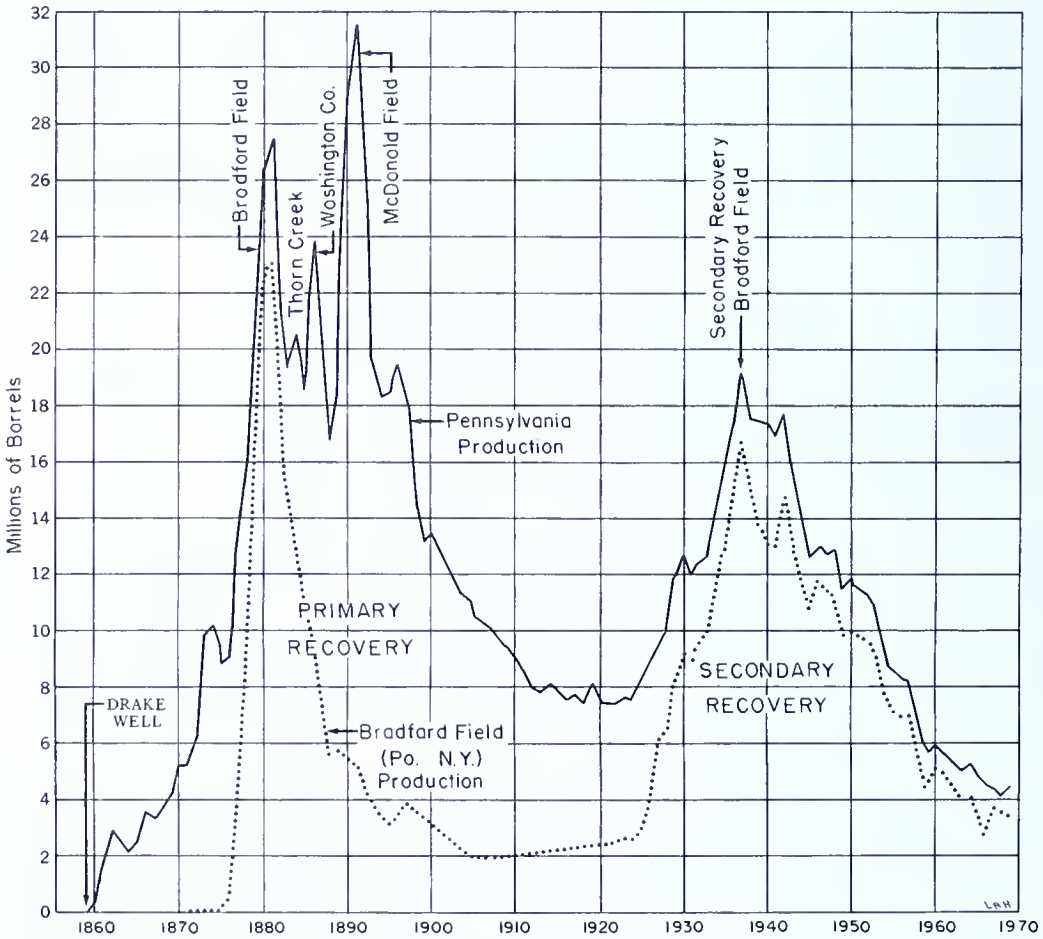


Figure 6. Annual production of crude oil in Pennsylvania.

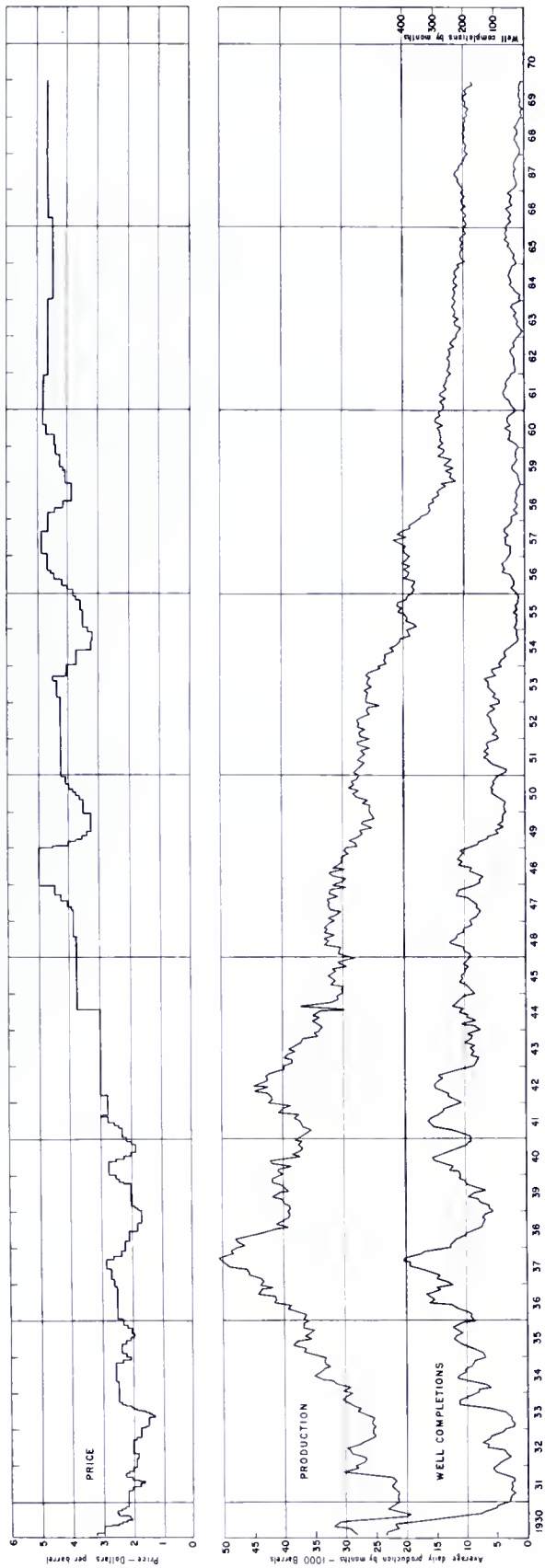


Figure 7. Crude oil prices, production, and completions, Bradford field.

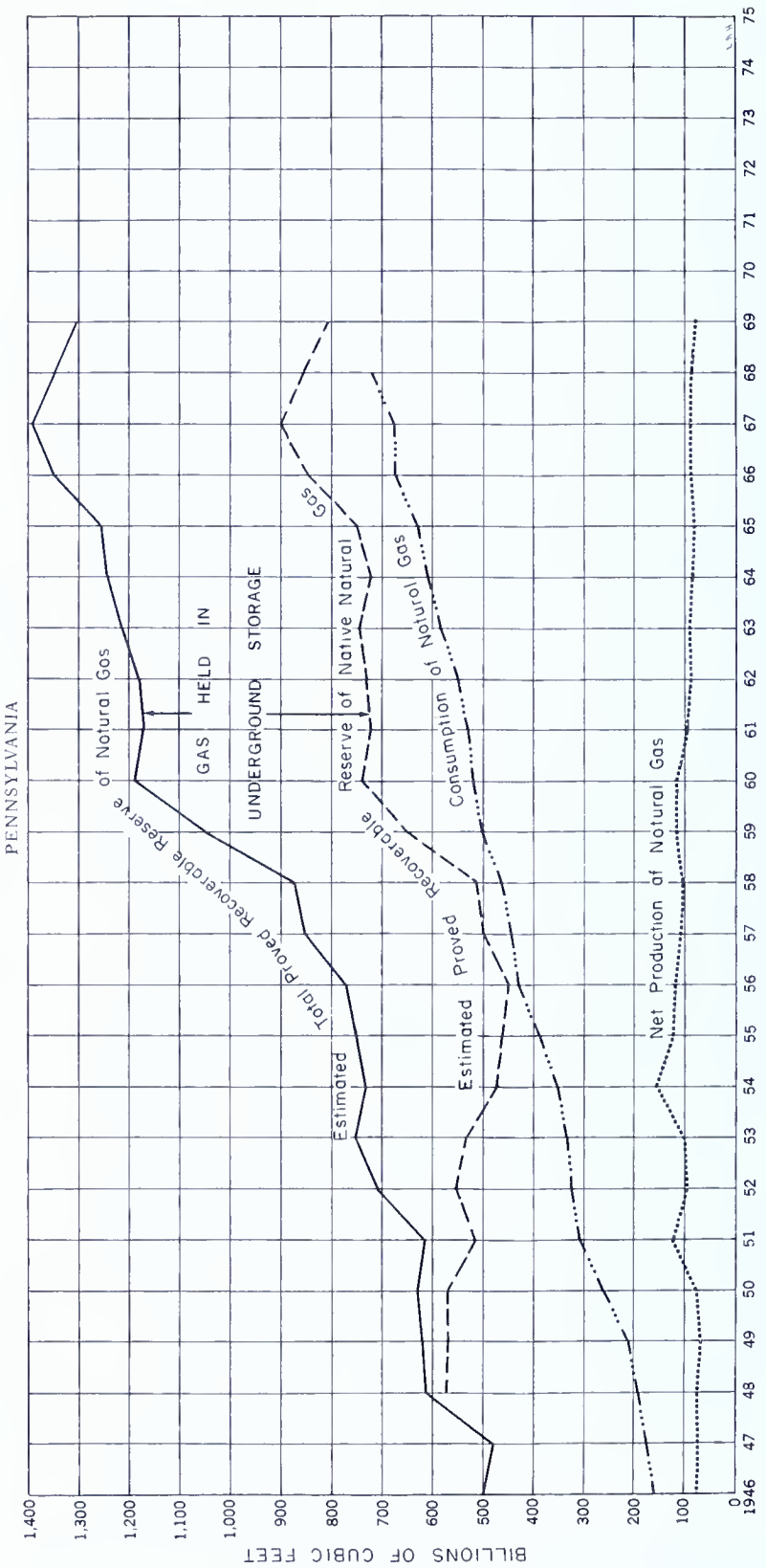
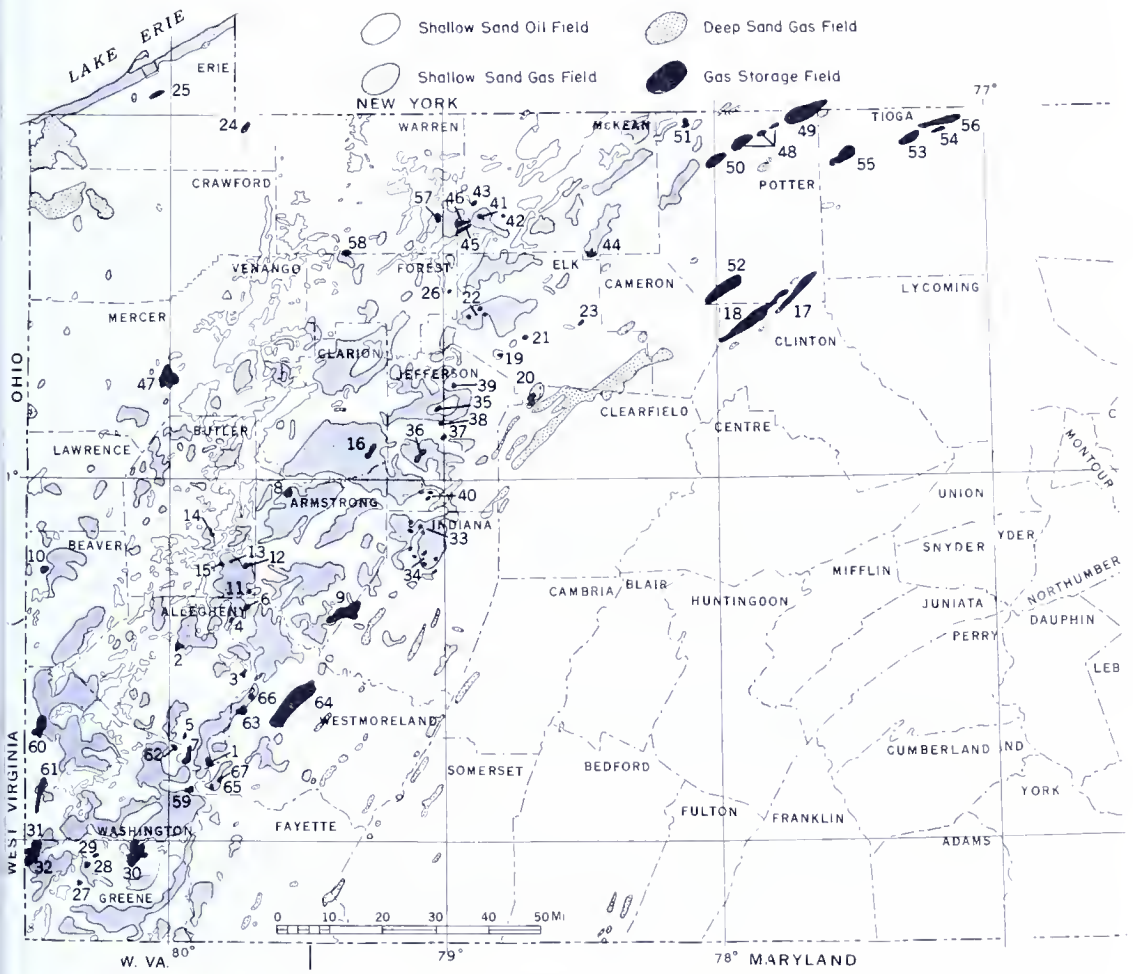


Figure 8. Production, consumption, and reserves of natural gas in Pennsylvania.



GAS STORAGE FIELDS

1. GAMBLE-HAYDEN
2. MT. ROYAL
3. MURRYSVILLE
4. TARENTUM STONE & COAL
5. TEPE
6. SLIGO
7. BUNOLA
8. FAIR-HELM
9. SOUTH BEND
10. SOUTH BEAVER
11. HUGHES
12. KEASEY
13. NEUBERT
14. PORTMAN
15. SAXONBURG
16. TRUITTSBURG
17. GREENLICK
18. LEIDY
19. BELMOUTH
20. BOONE MT.
21. MOHAN RUN
22. OWLS NEST
23. ST. MARYS
24. CORRY
25. MEADE (SUMMIT)
26. DUHRING
27. HOLBROOK
2B. HUNTERS CAVE
29. SWARTZ
30. PRATT
31. HEARD
32. MAJORSVILLE
33. ALABRAN
34. KINTER
35. BULLERS
36. GALBRAITH
37. IOWA
3B. MARKLE
39. MUNDERF
40. SPRANKLE
41. KEELOR
42. MEADE RUN
43. SWEDE HILL
44. WELLENDORF
45. EAST BRANCH "A"
46. EAST BRANCH "B"
47. HENDERSON
4B. ELLISBURG
49. HARRISON
50. HEBRON
51. SHARON
52. WHARTON
53. WEST TIOGA (PALMER)
54. MEEKER
55. SABINSVILLE
56. EAST TIOGA (BOOM)
57. DEERLICK
5B. QUEEN
59. COLVIN
60. CROSS CREEK
61. DONEGAL
62. FINLEYVILLE
63. IRWIN
64. OAKFORD
65. PATTON
66. TRAFFORD
67. WEBSTER

Figure 9. Map of gas storage fields in Pennsylvania.

Table 14. Deep-gas production in Pennsylvania, 1969 (in Mcf).

County	Field	Pool	Discovery Date	Cumulative Production at End of 1968	Production 1969	Cumulative Production at End of 1969	Status of Field or Pool at End of 1969
Armstrong	Shellhammer*	Rupert	11/14/58	360,422		360,422	Abandoned 1969
Bedford	Artemus	*TOTAL*	7/30/63	2,403,000	10,000	2,413,000	Producing
		Artemus	7/30/63	1,577,000	10,000	1,587,000	Producing
		Pennland	8/28/64	826,000		826,000	Producing
	Big Mt.		10/ 6/64	727,000		727,000	Abandoned 1969
	Five Forks		6/21/62	14,489,000	234,000	14,723,000	Producing
	Purcell		12/14/57	3,034,000	39,000	3,073,000	Producing
Cambria	Rager Mt.		10/16/65	6,438,381**	1,755,045	8,213,426	Producing
Cameron & Elk	Whippoorwill		7/10/61	13,429,000	433,000	13,862,000	Producing
Cameron, Elk,							Producing
Jefferson, Clearfield	Punxsutawney-*	*TOTAL*	9/15/51	462,014,000	3,969,000	465,983,000	Producing
and Indiana	Driftwood	Benezette	1/ 5/53	239,828,000	1,303,000	241,131,000	Producing
		Driftwood	9/15/51				Producing
		Boone Mt.	9/18/58	97,317,000	1,250,000	98,567,000	Producing
		DuBois	1/ 6/60				Producing
		Sabula	8/26/63	735,000	35,000	770,000	Producing
		Helvetia	5/11/60	120,338,000	1,301,000	121,639,000	Producing
		Reed-	5/ 9/55				
		Deemer	12/ 1/53				Producing
		Rockton	2/25/55				Producing
		Sykesville	11/10/60				Producing
		Hicks Run	6/ 7/56	3,796,000	80,000	3,876,000	Producing
Clinton & Potter	Leidy	*TOTAL*	1/ 9/50	159,771,989	114,686	159,886,675	Gas Storage & Prod.
		Ole Bull	1/ 9/59	4,971,957	114,686	5,086,643	Producing
Crawford & Erie	Conneaut	*TOTAL*	2/11/57	21,649,059	2,367,971	24,017,030	Producing & Aban.
		Bushnell-					
		Lexington	12/31/58	10,587,321	1,001,095	11,588,416	Producing
		Indian Springs	9/11/57	7,299,358	855,412	8,154,770	Producing
		Kastle	7/14/62	1,709,000	316,575	2,025,575	Producing
		Lundys Lane	11/ 9/61	1,139,347	89,868	1,229,215	Producing
		Pierce	12/31/58	538,302**	105,021	643,323	Producing
		Springfield	9/19/66	375,731		375,731	Abandoned (Oriskany) 1967
Erie	Burgess		10/17/60	127,552	5,051	132,603	Producing
	Corry	*TOTAL*	4/29/47	1,021,436	8,394	1,029,830	Gas Storage & Prod.
		Beaver Dam	5/20/53	167,736	8,394	176,130	Producing
	Meade		8/23/46	4,909,783	4,411	4,914,194	Oriskany Gas Storage (One Producing Medina Well)

Fayette	Ohiopyle		12/28/59	3,432,607	132,094	3,564,701	Producing
	Sandy Creek*		8/ 8/63	280,696	53,760	334,456	Producing
		Fike	8/ 8/63	280,696	33,760	314,456	Producing
		Quebec Run	6/31/69		20,000	20,000	Producing
	Spruell		10/13/61	706,429	446,352	1,152,781	Producing
	Summit	*TOTAL*	3/24/38	41,766,540**	227,100	41,966,490	Producing & Aban.
		North Summit	3/24/38	20,760,450**	74,647	20,835,097	Producing
		South Summit	5/ 9/42	20,978,940**	152,453	21,131,393	Producing
Indiana	Cherry Hill*	Crichton	1/ 9/63	2,366,594	132,982	2,499,576	Producing
		Hadden	7/11/63				
	Jacksonville		9/21/56	25,370,084	374,336	25,744,420	Producing
	Nolo		9/30/56	10,022,515**	300,000***	10,322,515	Producing
Jefferson	Big Run*	Elk Run	6/30/65	32,038,000	4,144,000	36,182,000	Producing
McKean	Mallory		12/ 1/60	132,783	1,340	134,123	Producing
Mercer	Henderson		10/26/66				Producing
	Wheatland		7/24/63	91,418	17,854	109,272	Producing
Potter	Ulysses		10/ 2/39				Producing
		New Field	4/ 2/62	3,155,316	140,365	3,295,681	Producing
Somerset	Boswell	*TOTAL*	11/11/58	9,545,706	419,046	9,964,752	Producing
		Boswell	11/11/58	8,743,019	378,724	9,121,743	Producing
		Snyder	6/16/60	802,687	40,322	843,009	Producing
Washington	Daniels Run*	Glyde	9/ 6/61	67,900	6,918	74,818	Producing
	Belle Vernon	Lover	8/14/68	7,506	15,549	23,055	Producing
Westmoreland	Blairsville*	Kahl	10/23/62	7,136,473	591,852	7,728,325	Producing
	Latrobe*	Dry Ridge	8/25/46	4,451,935	182,167	4,634,102	Producing
	Jacobs Creek*	Bailey	12/26/61	650,306	170,713	821,019	Producing
	Lycippus	*TOTAL*	8/17/49	5,696,881	133,870	5,830,751	Producing & Aban.
		St. Boniface Chapel	9/13/56	4,957,453	133,870	5,091,323	Producing
	Murrysville*	*TOTAL*	11/ 3/1878	339,225	45,594	384,819	Producing
		Sloan	10/22/63	122,793	718	123,511	Producing
Westmoreland & Somerset	Johnstown	Duquesne	8/ 8/65	216,432	44,876	261,308	Producing
		TOTAL	5/16/57	20,400,384	1,012,706	21,413,090	Producing & Aban.
		Baldwin	5/22/60	7,044,155	323,624	7,367,779	Abandoned
		Beck	5/16/57				Producing
		Williams	2/14/58	13,356,229	689,082	14,045,311	Producing
	Seven Springs	*TOTAL*	12/15/58	6,424,366	333,333	6,757,699	Producing & Aban.
		Blair	12/ 5/58	5,346,142	244,291	5,590,433	Producing
		Tunnel	3/10/65				
		Seven Springs	8/ 3/66	354,801	89,042	443,843	Producing

* "Shallow" Gas Production of Field Not Shown.
** Corrected Figures.
*** Estimated.

Description of most of the gas storage fields in Pennsylvania can be found in the 1963 Survey publication, "Underground Storage of Natural Gas in Pennsylvania," by W. S. Lytle, Bulletin M46. Some notes relative to changes since that publication can be found in last year's Oil and Gas Developments Progress Report 177, published in 1969.

Subsurface Disposal for Other Industry

A number of subsurface disposal projects were under consideration by major industry during the year. In response to the expanding interest in this field by both government and industry, particularly as attention to pollution increases, the Survey has sponsored a study of subsurface disposal. This project is nearing completion and should be made available this coming year. It will offer detailed principals and guidelines for this use of the subsurface, together with a general evaluation of the suitability of the subsurface rocks of Pennsylvania for disposal.

No additional disposal projects were completed during 1969. One well was drilled for disposal. The status of this well is awaiting evaluation of results of drilling and testing. Although the project was not completed during 1969 and therefore not carried in statistics, it has been included in Table 15 which lists all known disposal projects in the Commonwealth.

Secondary and Tertiary Oil Recovery Projects

Secondary and tertiary oil recovery activity is carried under the category of "Other" in statistics above (Tables 5, 7), and also nationally reported. An increase in these recovery projects is indicated although data reported to the State is inadequate to accurately establish the extent and results of recovery well and project developments. The last compilation and description of recovery projects in Pennsylvania is the 1960 Survey publication "History, Present Status and Future Possibilities of Secondary Recovery Operations in Pennsylvania," W. S. Lytle, Bulletin M41.

Of the six attempts at steam floods in the Pennsylvania oil fields, only one (Franklin-Oak Forest) seems to hold any promise of being economical. Although the injection of steam into the Franklin-Oak Forest project has been discontinued, it is thought that with refinements, adaptations, and innovations steam flooding in the Franklin Heavy oil field might be an adaptable process.

The two in situ (fire) flood projects were not economical. The first one was in the Venango First sand in the Goodwill Hill-Grand Valley field and the second one in the Venango Second sand in the Franklin

Table 15. Subsurface disposal projects in Pennsylvania.

Project and Operator	15-Minute Quadrangle, Section, Survey Map No.	County	Disposal Horizon: Depth (feet)	Disposal Horizon: Formation	Disposal Horizon: General Rock Type	Initial Completion: Type of Waste	Initial Completion: Injection Rate (GPM)	Initial Completion: Injection Pressure (psi)	Initial Completion: Date	Initial Completion: Status	Notes
Aliquippa Jones & Laughlin Steel Corporation	Sewickley D, #2 (Deep)	Beaver	4585-4635 5253-5445	Upper Devonian Onondaga Oriskany Helderberg	Shales Chert Sandstone Limestone	Steel Mill Pickle Liquor	100	5000	1/1966	Active	
Colerain Twp. Gulf Research & Development	Clearville A, #33 (Deep)	Bedford	545-563	Bellefonte	Dolomite	Drilling Mud	*	1000-1300	12/1964	Plugged and Abandoned 6/69	*Periodic injections amounted to 70,350 gallons cumulative.
Petrolia Borough Kopper Co., Inc. #1	Foxburg G, #64 (Shallow)	Butler	1827-1837 1907 2044 2160-2170	Warren First Warren Second Queen "Speechley"	Siltstone Siltstone Siltstone Sandstone	Organic Chem. Liquors: Sulfite, Sulphates Phenolics				Pending Completion	
Franklin Borough Bethlehem Steel Company	Johnstown E, #3 (Shallow)	Cambria	570-835	Big Injun	Sandstone	Weak Ammonia Liquor			1/1966	Abandoned	Inadequate reservoir on testing.
Erie Hammermill Paper Company #1	Erie F, #109 (Deep)	Erie	1610-1688	Bass Island	Dolomite	Spent Sulfite Pulping Liquor	350	1100	11/1965	Active	
Erie Hammermill Paper Company #2	Erie F, #110 (Deep)	Erie	1658-1732 5109-5972*	Bass Island Gatesburg	Dolomite Sandstone	Spent Sulfite Pulping Liquor	600-800	1100	9/1965	Shut-in *	*Gatesburg tested, not used for disposal.
Erie Hammermill Paper Company #3	Erie F, #113 (Deep)	Erie	1586-1737	Bass Island	Dolomite	Spent Sulfite Pulping Liquor	831	1100	8/1968	Active	
W. Bethlehem Twp. Bethlehem Steel Company	Amity H, #86 (Shallow)	Washington	1472-1508	"Salt"	Sandstone	Acid Mine Water			2/1966	Abandoned	Inadequately developed reservoir.

* Data from the Pennsylvania Department of Health.

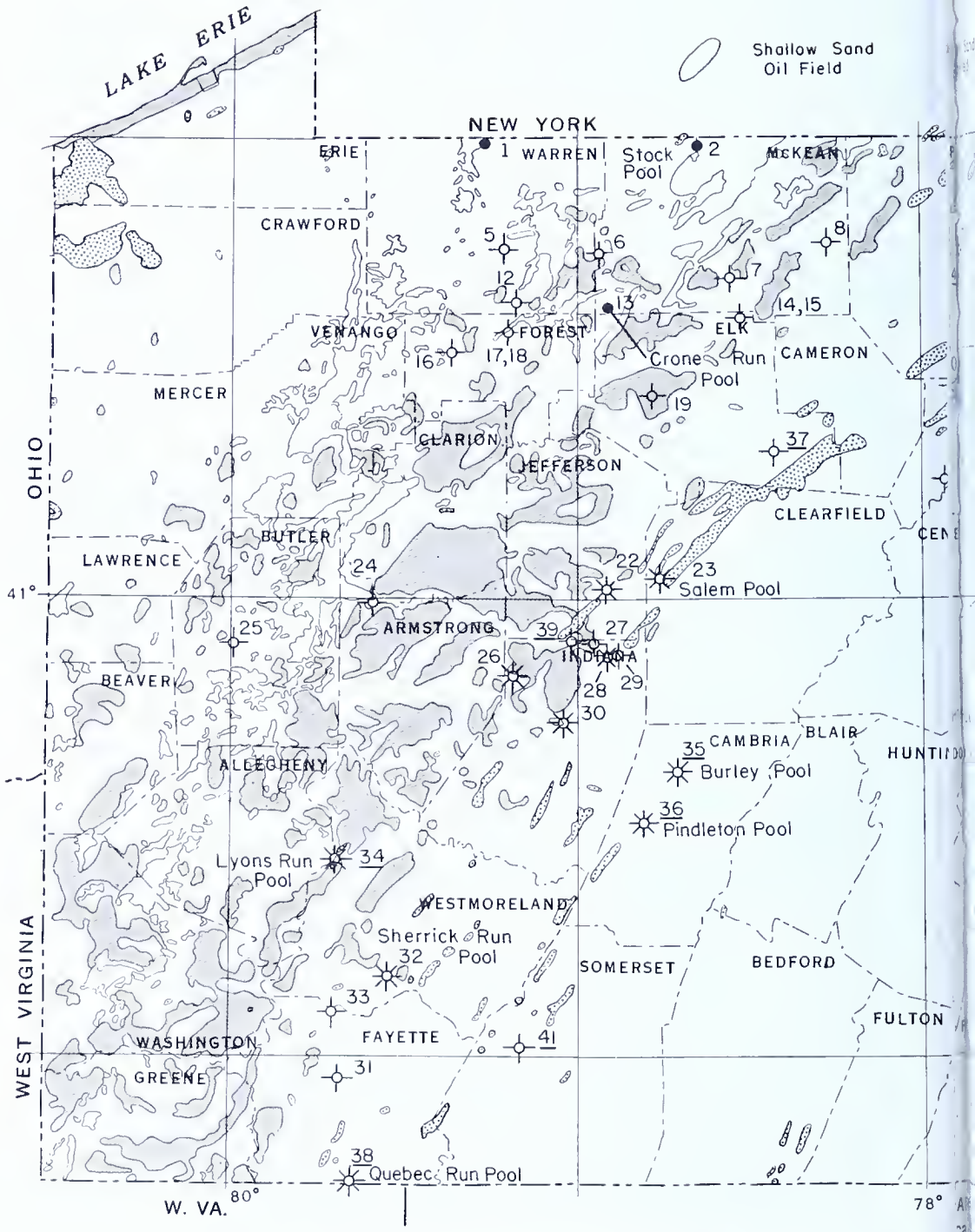
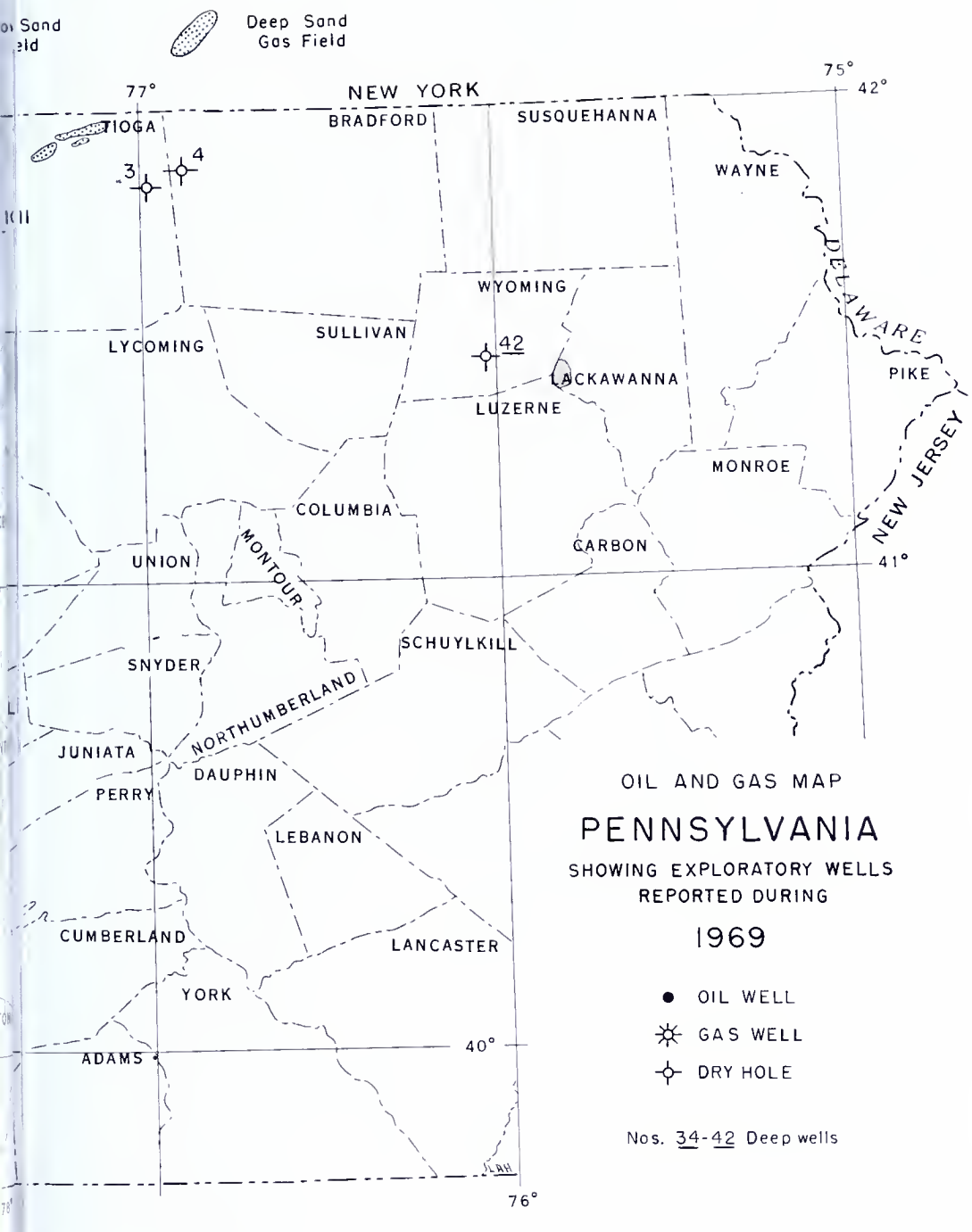


Figure 10. Oil and gas map o
reported during 19



a showing exploratory wells

area. Using the lessons learned in the first flood, the operators had greater success in the Franklin experiment. The oil sand in a well approximately 100 feet from the well in which the fire was initiated was completely devoid of oil. The oil had been moved and burned. The experience gained in the two floods points the way toward a third experiment.

The Maraflood Pilot Project in the Bradford field, McKean County is continuing. After injecting the micellar solution, mobility buffer and ordinary water into the Bradford Third sand, the project is in the experimental stage to see if the mechanism is adaptable to Penn Grade crude.

The miscible displacement flood in the Bradford Third sand of the Bradford Oil Field was unsuccessful. After injecting isopropyl alcohol, it was determined that an alcohol with a higher molecular weight should have been used. The alcohol was soluble in water but not in the Penn Grade crude. Therefore, a miscible mixture was not formed. The injection of the isopropyl alcohol did raise the viscosity of the mixture.

Flooding with water, gas and air continues in the Pennsylvania oil fields. Very few gas and air injection projects are in operation. The primary area for water flooding is still the Bradford field where very little acreage if any has yet to be flooded.

INDICATED EMPHASIS ON AREAS AND HORIZONS BY LOCAL INDUSTRY

The Pennsylvania Survey has initiated monthly tabulations of primary activity to aid in determining as soon as possible exploratory and development areas, trends, and changes, and in keeping track of activity during the year. Figure 11 graphically presents these monthly data. There is insufficient background information at this time to fully appraise such tabulations, nevertheless, Figure 11 illustrates a number of interesting factors relative to the local industry.

1. Activity is possibly seasonal; high receipt of reports in winter reflecting increased Fall or year end drilling activity.

2. Considering the number of wildcats drilled, (see Figure 4), activity in Pennsylvania is largely concentrated in reworking areas of known and historic shallow production, particularly for oil. Deep activity is similarly concentrated largely in known productive areas and formations, i.e., the extreme northwestern corner of the State for Medina production and the western edge of the folded belt for Oriskany production.

3. Although the majority of shallow completions are concentrated in only a few counties throughout the year, completions in "other" counties appear to increase toward the end of the year. This apparent trend could reflect expansion into other new areas, particularly for shallow gas (refer to Completion Highlights) south and east of established fields.

The concentration of primary activity reflects the Highlight plays previously discussed. Over 90 percent of shallow gas completions were made in the pre-Speechley sandstones, and over 50 percent of shallow oil completions in the Venango and Glade sandstones (most of the remaining oil completions are in and about the Bradford field). These development plays account for over 40 percent of the total number of dry holes.

OIL AND GAS PRICES

Crude oil prices during the year are shown in Table 16. The price for shallow gas averaged $0.26 per Mcf while deep gas averaged $0.275 per Mcf. A proposal received by the FPC but not yet approved requests the following ceilings per Mcf: existing gas $0.32, new shallow gas $0.34, and new deep gas $0.36.

Table 16. Crude oil prices per barrel, Pennsylvania 1969.

	Pennsylvania Grade Crude		
	Bradford District	*Middle District*	*Southwestern District*
Jan. 1-Dec. 31, 1969	$4.63		
Jan. 1-Mar. 31, 1969		$4.35	
Apr. 1-Dec. 31, 1969		Pennzoil United $4.19	
		Quaker State $4.35	
Jan. 1-Feb. 28, 1969			$4.08
Mar. 1-Dec. 31, 1969			$3.92
	Corning Grade Crude		
Jan. 1-Feb. 28, 1969	$2.87		
Mar. 1-Mar. 14, 1969	$2.92	Erie and Crawford counties	
Mar. 15-Dec. 31, 1969	$2.97		

LAND SALES

The Pennsylvania Game Commission leased tract 208 A with a bonus bid of $2,567.03 at a royalty bid of $0.04 per Mcf of gas and a rental of $1 per acre on a total of 785 acres in Gaines Township, Tioga County. At the end of 1969, the Commission had 24 active leases totaling 13,613 acres. Thirty-five wells were producing on 18 of these leases. Only one well was drilled on Game Commission lands during the year.

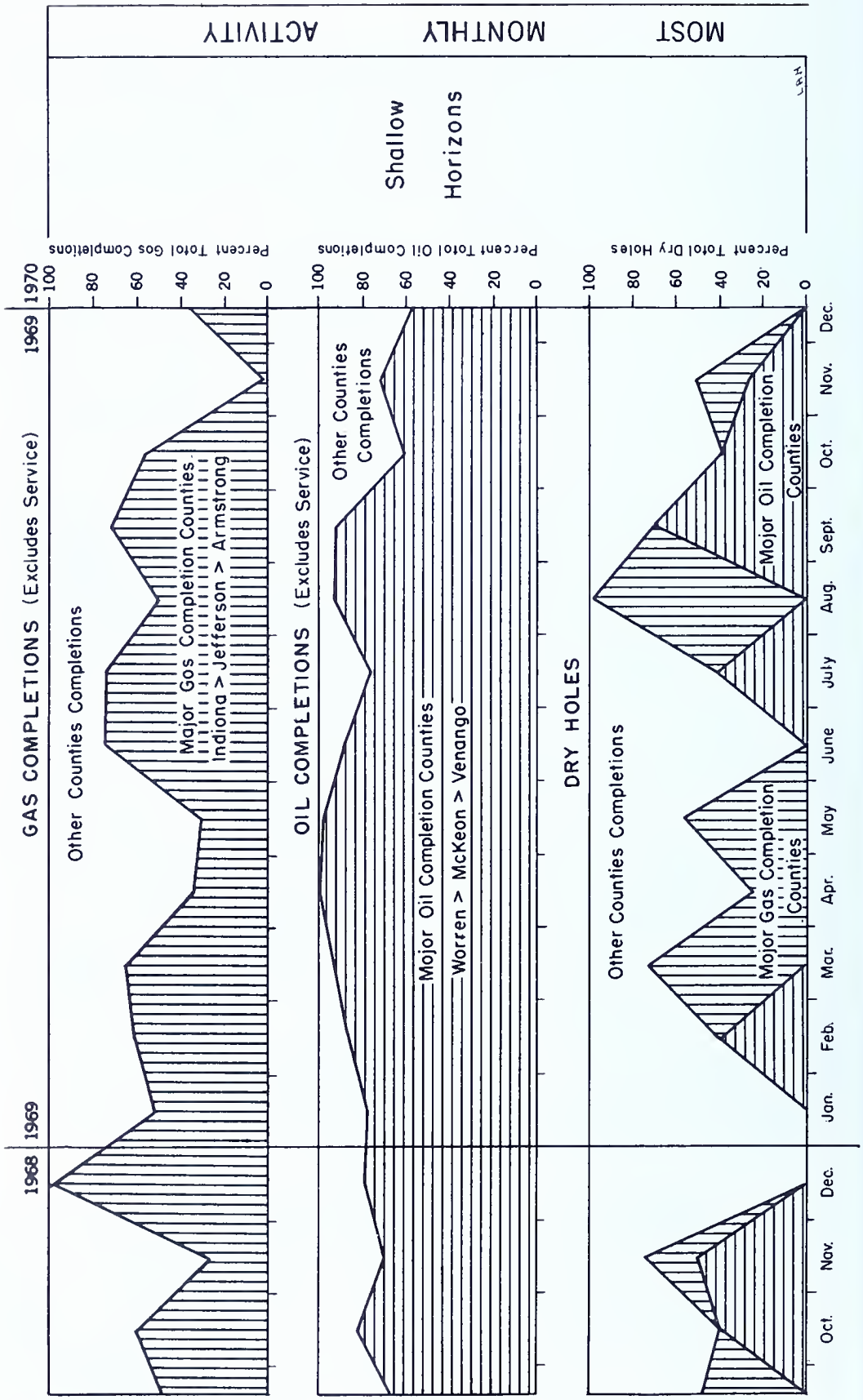
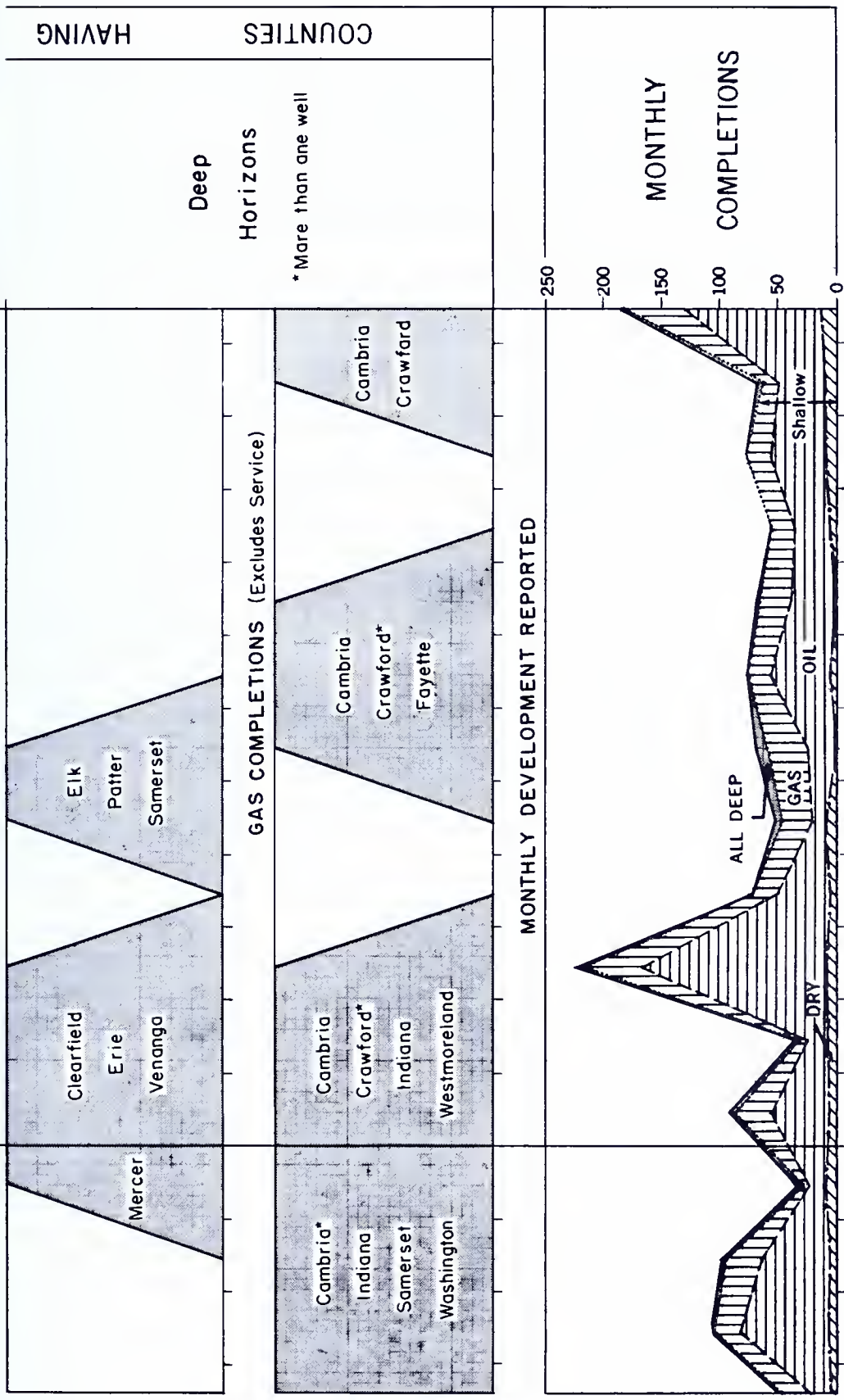


Figure 11. 1969 Pennsylvania



evelopments—where and when.

Through competitive bidding 1,100 acres of State Forest lands were leased at $8.17 per acre. A total bonus of $8,987 was received for this tract which carries a yearly rental of $1 per acre.

At the end of 1969, there were 144,983 acres of State Forest lands under lease for oil and gas exploration and development including 59,109 acres in gas storage. The total rental and royalty payments received relative to oil and gas exploration and development on State Forest lands for 1969 amounted to $354,477.

GEOPHYSICAL ACTIVITY

There were no gravity or magnetometer surveys reported in Pennsylvania during 1969. Seismic evaluation, however, increased from 23 crew-weeks in 1968 to 39 crew-weeks this past year. This activity was centered in three areas: immediately in front of the folded belt in northern central Pennsylvania in Cameron and Potter Counties, in McKean County, and in northwestern Pennsylvania in Mercer County.

CHANGES IN OIL AND GAS LAWS

During 1969 an amendment to the Oil and Gas Laws of Pennsylvania was submitted and approved in March 1970 (Senate Bill 1111). The laws are amended by adding a new Article VI, Regulation of Underground Gas Storage Reservoirs not covered under Article III. The amendment requires the operators of all gas storage reservoirs that did not come under Article III to file with the Oil and Gas Division of the Department of Mines and Mineral Industries certain maps and data showing the location of the storage reservoir and the locations of all wells drilled into or through the storage stratum within the reservoir or within three thousand linear feet thereof. Pertinent data such as total depth of well, production, initial rock pressure, etc. must be submitted on all wells. The regulations pertain to any person who wants to operate a new gas storage reservoir or recondition one that is operating. The obligations and requirements are described for each case.

POOL UNITIZATION—A GROWING TREND IN DEEP GAS DEVELOPMENT

The decline in deep drilling activity in the past several years can largely be attributed to the completion of development of known areas of Medina gas production in Erie and Crawford Counties. Another more subtle cause of decrease in deep drilling is the decline in the number of development wells to be drilled in recently discovered Onondaga-Oriskany gas pools. This decline is, in many respects, a healthy sign for the future of deep exploration in Pennsylvania.

In the past, strict application of the "Law of Capture" and consequent emphasis on speed of gas production led to wasteful overdrilling of many deep gas pools, notably in the Leidy and Punxsutawney-Driftwood fields. The present emphasis on greater gas recovery per well drilled, with attendant reduction of overall drilling and production costs, has led to a more rational approach to development planning.

The most logical way to eliminate excess wells is by unitization of the potentially productive acreage of a pool, and division of this total acreage into geologically and economically planned drilling and production units. Each operator participates in a drilling unit in proportion to the acreage contributed by him to the unit. Formal unitization under the Commonwealth Oil and Gas Conservation Commission is in effect in the Rager Mountain pool, and is pending for the Burley pool. The Pindleton pool has been unitized on an informal voluntary basis. At the time of writing (March 1970) unitization has been requested for the Grip (Pineton) pool.

The following table sums up the present status of planned or currently unitized acreage in these pools.

Table 17. Unitization programs in four pools.

Pool	*Unit Area Total*	*Actual or Planned Drilling Units*	*Total Drilling Unit Acreage*
Rager Mountain	7,462 acres	7 wells on 640 acre units	4,480 acres
Burley	3,200 acres	5 wells on 640 acre units	3,200 acres
Pindleton	5,760 acres	9 wells on 640 acre units	5,760 acres
Grip (Pineton)	18,675 acres	17 wells on 320 acre units	
		1 well on a 390 acre unit	6,230 acres
		1 well on a 400 acre unit	
TOTALS		40 wells	19,670 acres

If the total acreage in the drilling units were developed using 143.6 acres per well, the average per well spacing in the un-unitized Elk Run pool (Heyman, 1969), there would have to be 137 wells drilled. The decrease by two-thirds in the number of wells drilled/to be drilled thus does not represent a real decrease in activity.

Not only does this decrease represent a savings of some magnitude to the operators concerned, it also represents a considerable amount of capital made available for more extensive exploration and wildcat drilling.

INDUSTRY RELATED ACTIVITY

Exploratory Interest in Deep Horizons Expands in 1969

During 1968 exploratory interest focused on reefing in the Silurian Guelph or Lockport dolomites and in the Devonian Onondaga limestone in northwest Pennsylvania, as well as on the importance of Salina salt solution in determining Oriskany traps and delineation of deeper prospects (Progress Report 177). This interest has continued during 1969 with visits and inquiries by exploration geologists.

The recent discovery of Cambro-Ordovician gas just west of Pennsylvania in eastern Ohio has also stimulated a flurry of deep formation investigation and evaluation of Pennsylvania's future potential. Pennsylvania's prospects for discovery of significantly large gas reserves from deep horizons near major markets are excellent.

Importance of Subsurface Data in Evaluation of Resources

The need for subsurface resources for extraction, storage and disposal has produced a rapidly expanding demand for subsurface data and expertise. This demand can best be met by those experienced in subsurface geology-engineering. The oil and gas industry and related services can play an important role in filling this need.

There are two aspects in which those engaged in subsurface activities can significantly implement the evaluation of resources other than oil and gas. The first is in projection of these resources from the surface or near surface into the underground. The second aspect is in definition of these resources.

Whether the purpose is determination of the extent of deposits of potential minable resources, the distribution of fresh water or unstable construction zones, carefully described sample information, full hole geophysical logs, and to a lesser extent, scout tickets and drillers logs, provide valuable information. Within a few thousand, or even hundreds of feet from the earth's surface, coals, refractory clays, flux limestones, construction rock, fresh water sandstones, mobile clays, and other zones of importance occur in the Mississippian, Pennsylvanian, and Devonian strata. Gross thickness changes in the shallow subsurface can be ascertained from currently available subsurface well data. The "economic" limits of these deposits can be defined or established from subsurface information. Pennsylvania operators are urged to keep accurate information on drilling results; lithology and thickness of the different rocks encountered, drilling rates, occurrences of fluids, depth of caving and lost circulation, and so forth. Regardless of whether these factors are deemed

important to the evaluation of the prime objectives for the well, they are of immense importance in other contexts.

Operators should also be aware of the present or potential economic value of rock types encountered, again whether or not they are significant in the evaluation of oil and gas. Qualitative estimates, tests, or logs should be made or taken to determine for future economic reference the possible value of rock materials penetrated. Were the sandstones friable and porous, or dense and hard? What was the volume of water in what period of time? Was it salty or fresh? What was the color of the limestones or shales? Were they relatively free of other material? Was it coal or coaly shales that were recovered? All of these and many other similar questions should be answered, much less logs or tests made, if the operator or driller is to reliably fulfill his obligation to the land owner, and if the land owner really desires to establish the total value of the property being drilled.

Perhaps other resources may be of more value than the oil or gas. Listed below are some of the non-gas and oil resources in western Pennsylvania that have present or potential economic value, and the evaluation of which may be largely dependent on subsurface data and knowledge.

Fluids

Brines for chemicals
Fresh water for domestic and industrial uses

Non-metallic minerals

Coal for fuel and chemicals
Limestone for cement, flux, chemical, agricultural, building aggregate, and other uses
Clay for cement, bricks, tiles, ceramics, building aggregate, and other uses
Sand and gravel for building aggregate
Stone for construction
Salt for chemicals

Environmental considerations

Reservoirs for disposal
Resistant limestones and sandstones for construction foundation
Mobile clay and solution-susceptible limestone and sandstone as construction hazards
Fracture systems which may affect fresh water aquifers and stability of nearby slopes

Availability of Survey Subsurface Data

The Pennsylvania Geological Survey has initiated projects designed to make readily available all subsurface information on file. Progress on these projects is outlined below.

1. *Subsurface Base Maps*—Paper prints of the initial four well location base maps with superimposed field outline are now available. Each base (scale 1: 62,500) comprises the area of four 15 minute topographic quadrangles and locates all post-Oil and Gas Law shallow wells and all deep wells of record as described in PR 177. Figure 12 indexes available base maps. Orders for these maps are to be sent to the Pennsylvania Bureau of Publications, 10th and Market Streets, Harrisburg, Pa. 17125. The available base maps are:

Designation	*Quadrangles Encompassed by Mapped Area*
Map 16	Corry, Tidioute, Titusville, Youngsville
Map 17	Kane, Kinzua, Sheffield, Warren
Map 18	Clarion, Foxburg, Oil City, Tionesta
Map 19	Brookville, DuBois, Hallton, Marienville

An index showing the location of the completed bases may be obtained upon request from the Pittsburgh Branch of the Pennsylvania Geological Survey, 401 Pittsburgh State Office Building, 300 Liberty Avenue, Pittsburgh, Pa. 15222. A cross index of state permit numbers with quadrangle map numbers used on the base maps is also available from the Survey. This index is arranged by quadrangles. Please specify the quadrangle when requesting this listing.

2. *Deep Base Map of Pennsylvania*—Paper prints of a 1: 500,000 base showing all "Salina or Equivalent and Deeper Penetrations of Pennsylvania" can now be obtained through the Oil and Gas Division, Pennsylvania Geological Survey, 401 Pittsburgh State Office Building, 300 Liberty Avenue, Pittsburgh, Pennsylvania 15222. This base map shows all wells which have penetrated 400 feet into the Salina or equivalent horizons or deeper. Post Ordovician, post Trenton-Black River or equivalent, and Trenton-Black River and deeper wells are distinguished by different symbols. Only the Trenton-Black River and deeper wells are spotted in Erie and Crawford Counties. Quadrangle well number, elevation, total depth, and availability of geophysical log and sample information are shown for each well. The base includes county and

15 minute topographic quadrangle boundaries, section ticks, major cities, and the western limit of Silurian outcrops.

3. *Brine Analyses*—All deep formation brine analyses on file have been compiled and tabulated by horizon. A 1: 500,000 base map shows the regional location of wells from which recovered waters were analyzed and the resistivity (Rw) of these waters by horizons. All shallow brine analyses have been compiled by previously defined Upper Devonian zones A, B, C, and D (Progress Report 178), but are not tabulated or indexed on a map. These data have been placed in open file.
4. *Regional Log Sections*—The Upper Devonian to surface cross-sectioning program is continuing. Some of these sections should be available as paper prints toward the end of 1970. A similar deep cross-section program of the Devonian Tully to Queenston interval in western Pennsylvania was initiated.

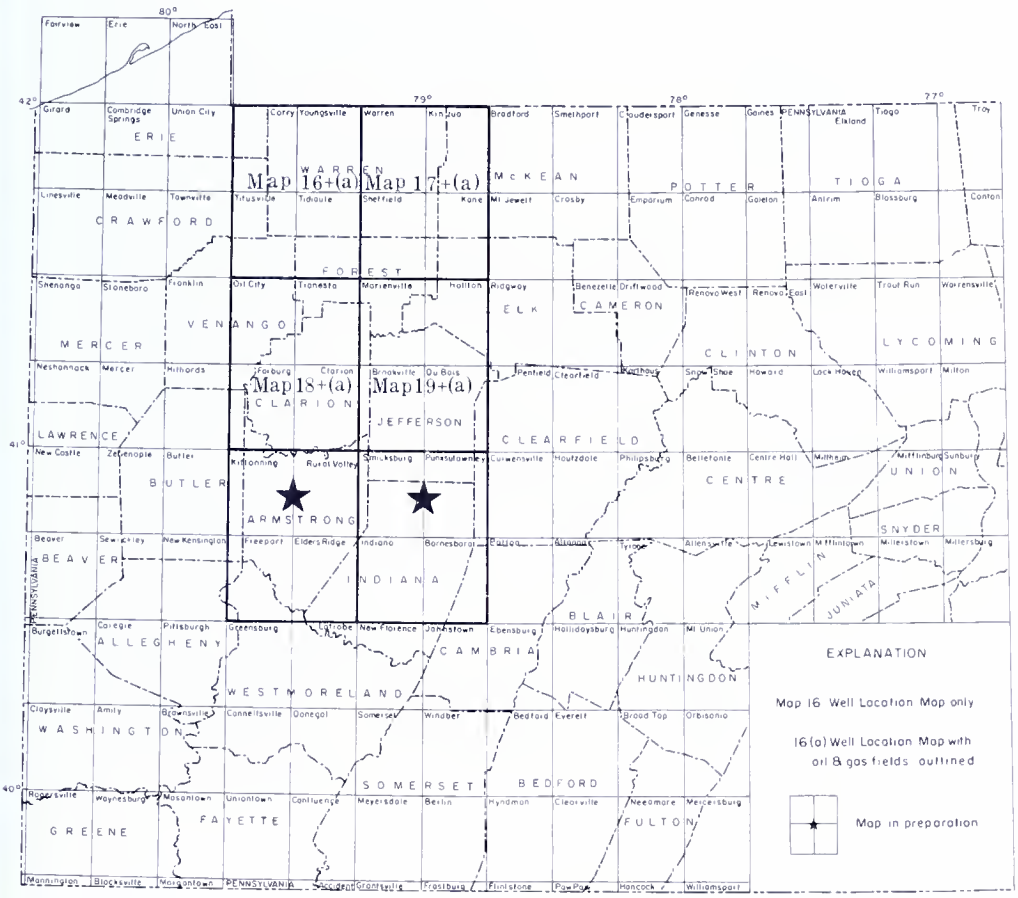


Figure 12. Index of available base maps showing shallow and deep well locations.

PART III. SUMMARIZED RECORDS OF DEEP WELLS REPORTED IN 1969

Reference is made to the previous section on "Benefit of Well Data and Basis for Statistics" (Part II) noting that all reports of oil and gas industry activity within the Commonwealth have been made consistent and are based on official reports of drilling or completion received from the Department of Mines and Mineral Industries, Oil and Gas Division, the regulatory agency for Oil and Gas Laws, in Pennsylvania within the calendar year.

The information in the following tables has been compiled mainly from drillers' logs and location plats received from the Oil and Gas Division of the Commonwealth, Department of Mines and Mineral Industries. Other sources are the commercial scout information service, Petroleum Information Corporation (PI), geophysical logs received by the Pennsylvania Geological Survey and personal communications with oil and gas operators. The identification numbers in Table 18 refer only to well location numbers on Figure 10 of this report. The more significant numbers are the permit numbers by which the wells are filed with the Department of Mines and Mineral Industries and the more exclusive and specific quadrangle numbers by which the Survey files the wells and locates them on 15 minute quadrangle maps. An asterisk preceding a certain depth figure indicates that the indicated formation top has been picked from a geophysical log. A depth figure without asterisk means that the formation top is from the drillers' log or PI.

Table 18. Summarized records of deep wells drilled in 1968.

MAP NUMBER	35	36								
COUNTY Permit Number	Cambria 14	Cambria 15	Cambria 17	Clearfield 419	Crawford 235	Crawford 240	Crawford 238	Crawford 247	Crawford 237	Crawford 249
NAME OF WELL	F. G. Burley 1	Albert Kubat 1	Webster Griffith 1	Kewanee O & G 1	T. D. Askey 1	Edith Foster (J. T. Cadle) 1	J. W. Foster 1	Francis Hites (Edna McClinton) 1	C. W. McCormick 1	Lloyd R. Nelson 2
OPERATOR	Kewanee Oil et.al.	Peoples Natural Gas Co.	Peoples Natural Gas Co.	Lee E. Minter	James Drilling Corp.	Stanley J. Kerpoe	James Drilling Corp.	Stanley J. Kerpoe	James Drilling Corp.	James Drilling Corp.
TOWNSHIP	West Carroll	Blacklick	Blacklick	Huston	Spring	Spring	Spring	Spring	Spring	Spring
QUADRANGLE	Patton D 2	Barnesboro I 17	Johnstown C 12	Penfield E 282	Girard I 390	Girard I 394	Girard I 392	Girard I 395	Girard I 393	Girard I 389
LATITUOE	13,000 ft. S 40°40'	26,850 ft. S 40°35'	1,100 ft. S 40°30'	9,450 ft. S 41°10'	24,800 ft. S 41°50'	22,500 ft. S 41°50'	20,300 ft. S 41°50'	18,250 ft. S 41°50'	20,650 ft. S 41°50'	16,900 ft. S 41°50'
LONGITUOE	10,900 ft. W 78°40'	18,300 ft. W 78°45'	22,300 ft. W 78°45'	20,100 ft. W 78°35'	16,100 ft. W 80°15'	15,800 ft. W 80°15'	16,100 ft. W 80°15'	15,100 ft. W 80°15'	17,500 ft. W 80°15'	20,250 ft. W 80°15'
DATE COMPLETEO	1-13-69	7-2-69	12-5-69	2-14-69	10-31-68	12-28-68	12-27-68	2-26-69	12-20-68	9-20-68
ELEVATION	2069 KB	2239 GL	2026 GL	1580 KB	1242 topo	1221 topo	1210 topo	1222 topo	1224 topo	1259 GL
TULLY	*7462-7488	*7543-7568	*7480-7502	*6689-6789	2431-2471	2402-2439	2392-2435	2384-2428	2390-2428	
ONONDAGA Chert	*8304-8322 *8322-8395	*8470-8488 *8488-8577	*8338-8355 *8355-8438	*7263-7278 *7278-7337	2604-2824	2559-2761	2567-2735	2558-2753	2560-2755	2615-2840
ORISKANY	*8395-8410	*8577-8600	*8438-8494	*7337-						2840-2850
SALINA Salt					3200-	3125-	3110-	3003-	3130-	3060-
GUELPH-LOCKPORT					3500-	3455-	3448-	3430-	3453-	3432-
CLINTON IRONDEQUOIT					3839-	3792-	3786-	3757-	3790-	3772-
MEDINA WHIRLPOOL					3872- 4051-4059	3826- 3994?-4002	3819- 3998-4002	3798- 3976-3985	3823- 4000-4006	3804- 3980-3984
QUEENSTON					4059-	4002-	4002-	3985-	4006-	3984-
MIDDLE ORDOVICIAN LIMESTONES										
GATESBURG										
TOTAL DEPTH	8462	8634	8514	7360	4096	4015	4020	4017	4018	4016
DEEPEST FORMATION REACHED	Helderberg	Helderberg	Helderberg	Oriskany	Queenston	Queenston	Queenston	Queenston	Queenston	Queenston
RESULT	410 Mcf from Don-Dor @ 8395 2,100 Mcf AF, 3836 psi/48 hrs. Discovery, Burley pool	2,000 Mcf at 8577 4,750 Mcf AF, 3845 psi/5 days Discovery, Pindleton pool	731 Mcf from 8445 and 8475; 3,700 Mcf AF, 3839 psi/7 days	Salt water in Oriskany Abandoned	500 Mcf and 25 BO AF 3926-3963 1220 psi/3 days	3,000 Mcf AF 3879-3912 1220 psi 3 days	2,500 Mcf AF 3871-3912 1230 psi 3 days	1,500 Mcf AF 3853-3881 1225 psi 3 days	5,000 Mcf AF 3873-3910 1225 psi 3 days	1,200 Mcf AF 3847-3872 1210 psi 7 days

Table 18. Continued.

MAP NUMBER								37		38
COUNTY Permit Number	Crawford 234	Crawford 248	Crawford 245	Crawford 246	Crawford 241	Crawford 242	Crawford 330	Elk 134	Erie 312-P	Fayette 94-D
NAME OF WELL	Lucille Nelson 1	W. V. Onderko 2	Richard N. Panko (R. W. Cousins) 1	J. L. Rash (Nina J. Smith) 1	A. C. Surrarrer 1	Mary E. Smith 1	Chester Smith 2	Fee 1	C. Howland 1	Clifford L. Ryan 2
OPERATOR	Stanley J. Kerpoe	James Drilling Corp.	Stanley J. Kerpoe	Stanley J. Kerpoe	James Drilling Corp.	James Drilling Corp.	J. Sterling McCluskey	The Sylvania Corp.	Flanigan Bros.& Penna. Gas Co.	Zenith Exploration Co.
TOWNSHIP	Spring	Spring	Summerhill	Spring	Spring	Spring	Beaver	Jay	Springfield	Wharton
QUADRANGLE	Girard I 388	Girard I 387	Girard I 396	Girard I 398	Girard I 397	Girard I 399	Girard G 400	Benezette G 299	Girard A 386	Bruceton B 11
LATITUDE	16,800 ft. S 41°50'	23,700 ft. S 41°50'	29,900 ft. S 41°50'	28,550 ft. S 41°50'	27,050 ft. S 41°50'	27,200 ft. S 41°50'	19,850 ft. S 41°50'	5,850 ft. S 41°20'	21,050 ft. S 42°00'	10,350 ft. S 39°45'
LONGITUDE	18,550 ft. W 80°15'	18,000 ft. W 80°15'	18,200 ft. W 80°15'	16,600 ft. W 80°15'	15,400 ft. W 80°15'	17,550 ft. W 80°15'	3,600 ft. W 80°25'	4,250 ft. W 78°25'	8,150 ft. W 80°25'	18,020 ft. W 79°35'
DATE COMPLETED	10-20-68	10-10-68	12-30-68	3-17-69	3-16-69	3-27-69	8-15-69	6-3-69	9-10-68	6-3-69
ELEVATION	1251 GL	1251 GL	1320 topo	1255 topo	1240 topo	1260 topo	1090 topo	1721 KB	757 GL	1702 KB
TULLY			2530-2570	2472-2511	2448-2486	2459-2500		☆6433-6542	1458-1470	7135-7194
ONONDAGA Chert	2600-2805	2584-2776	2700-2888	2644-2830	2616-2820	2638-2825	2322-2562	☆7038-7054 ☆7054-7086	1626-1892	7639-7652 7652-7782
ORISKANY	2805-2815	2776-2786					2562-	7086-7100	1892-	7794-7892
SALINA Salt	3040-		3156-	3195-	3170-					
GUELPH-LOCKPORT	3456-	3495-	3610-	3548-	3522-	3535-	3205-			
CLINTON IRONDEQUOIT	3794-	3832-3842	3948-	3891-	3853-	3878-	3552-			
MEDINA WHIRLPOOL	3827- 4005-4010	3864- 4042-4048	3980- 4162-4170	3924- 4100-4108	3897- 4072-4076	3910-4001 4088-4096	3610-			
QUEENSTON	4010-	4048-	4170-	4108-	4076-	4096-	3770-			
MIDDLE ORDOVICIAN LIMESTONES										
GATESBURG										
TOTAL DEPTH	4020	4066	4200	4133	4080	4101	3810	7105	1913	7950
DEEPEST FORMATION REACHED	Queenston	Queenston	Queenston	Queenston	Queenston	Queenston	Queenston	Helderberg	Oriskany	Helderberg
RESULT	1,250 Mcf AF 3882-3912 1220 psi 7 days	2,500 Mcf AF 3922-3957 1225 psi 7 days	1,000 Mcf AF 4034-4069	750 Mcf AF 3966-4003 975 psi 6 days	1,500 Mcf AF 3948-3978 1075 psi 3 days	1,250 Mcf AF 3982-4008 1175 psi 3 days	1,000 Mcf AF 3653-3668 1185 psi 48 hrs.	22 Mcf @ 7,090 430 Mcf AF, blew down to 75 Mcf 2850 psi/131 hrs. Abandoned	212 Cf@ 1893-1897 1,200 ft. SW@ 1897-1913 Abandoned	492 Mcf @ 7657-7688 2,500 Mcf AF 3400 psi/72 hrs. Discovery

MAP NUMBER	39	40								
COUNTY Permit Number	Indiana 1082	Potter 295-R	Potter 296	Potter 297	Potter 305	Potter 301	Potter 299	Potter 290	Potter 288	Potter 284
NAME OF WELL	H. N. Mauk 1	Cizek P-1	G. L. Webster 1	G. L. Webster 2	Dana Greene 1	W. C. Allis 1	F & M. P. Estes 1	C. L. Long Wh-88	Pa. Dept. F & W Wh-90	Pa. Dept. F & W Wh-83
OPERATOR	Consol. Gas Supply Corp.	Pennzoil United, Inc.	Consol. Gas Supply Corp.	Consol. Gas Supply Corp.	Consol. Gas Supply Corp.	Consol. Gas Supply Corp.	Consol. Gas Supply Corp.	United Natural Gas Co.	United Natural Gas Co.	United Natural Gas Co.
TOWNSHIP	North Mahoning	West Branch	Genesee	Genesee	Genesee	Genesee	Genesee	Wharton	Wharton	Wharton
QUADRANGLE	Smicksburg F 35	Galeton A 43	Genesee B 149	Genesee B 151	Genesee B 152	Genesee B 150	Genesee B 153	Driftwood C 118	Driftwood C 119	Conrad G 51
LATITUDE	3,950 ft. S 40°55'	29,250 ft. S 41°45'	28,400 ft. S 42°00'	30,200 ft. S 42°00'	28,050 ft. S 42°00'	25,550 ft. S 42°00'	30,100 ft. S 42°00'	1,400 ft. S 41°30'	4,875 ft. S 41°30'	23,700 ft. S 41°35'
LONGITUDE	6,100 ft. W 79°00'	17,100 ft. W 77°40'	22,100 ft. W 77°50'	20,350 ft. W 77°50'	19,175 ft. W 77°50'	13,600 ft. W 77°50'	12,850 ft. W 77°50'	8,175 ft. W 78°00'	5,500 ft. W 78°00'	18,025 ft. W 77°55'
DATE COMPLETED	7-18-68	4-2-69	8-7-69	9-9-69	9-9-69	8-4-69	10-23-69	9-4-68	7-25-68	7-26-68
ELEVATION	1368	1889 KB	2139	2145	1998	2094	2134	1814 KB	1869 KB	2209 KB
TULLY	☆6716-6860	5262-5328	4635-4680	4566-4617	4440-4480	4535-4578	☆4562-4611	5358-5433	5370-5446	5718-5782
ONONDAGA LIMESTONE	☆7310-7332	6105-6128	5230-5250	5196-5210	5075-5095	5160-5178	☆5170-5198	6071-6086	6065-6086	6411-6433
ONONDAGA CHERT	☆7332-7405									
ORISKANY	☆7405-7435	absent	5250-5280	5210-5242	5095-5130	5178-5206	☆5198-5223	6086-6112	6086-6114	6433-6464
HELDERBERG	7435-	6128-6307	5280-	5242-	5130-	5206-	5223-	6112-	6114-	6464-
SALINA		Bass Islds. Dol. 6307-								
GUELPH-LOCKPORT										
CLINTON										
MEDINA										
QUEENSTON										
TOTAL DEPTH	7465	6311	5345	5310	5181	5278	5293	6160	6158	6493
DEEPEST FORMATION REACHED	Helderberg	Bass Islands	Helderberg	Helderberg	Helderberg	Helderberg	Helderberg	Helderberg	Helderberg	Helderberg
RESULT	NSG Oriskany PB 3600 Compl. for shallow gas from Bradford Third Sand	SG in Hamilton Oriskany absent Abandoned	Ellisburg Gas Storage	Ellisburg Gas Storage	Ellisburg Gas Storage	Ellisburg Gas Storage	Ellisburg Gas Storage	East Fork-Wharton Gas Storage	East Fork-Wharton Gas Storage	East Fork-Wharton Gas Storage

Table 18. Continued.

MAP NUMBER										
COUNTY Permit Number	Potter 285	Potter 291	Potter 280	Potter 281	Potter 282	Potter 283	Potter 286	Potter 287	Potter 292	Potter 289
NAME OF WELL	Pa. Dept. F & W Wh-84	C. R. Peters Wh-86	Pa. Dept. F & W Wh-79	Pa. Dept. F & W Wh-80	Pa. Dept. F & W Wh-81	Pa. Dept. F & W Wh-82	Pa. Dept. F & W Wh-85	Pa. Dept. F & W Wh-87	C. R. Peters Wh-89	Pa. Dept. F & W Wh-91
OPERATOR	United Natural Gas Co.	United Natural Gas Co.	United Natural Gas Co.	United Natural Gas Co.	United Natural Gas Co.	United Natural Gas Co.	United Natural Gas Co.	United Natural Gas Co.	United Natural Gas Co.	United Natural Gas Co.
TOWNSHIP	Wharton	Wharton	Wharton	Wharton	Wharton	Wharton	Wharton	Wharton	Wharton	Wharton
QUADRANGLE	Conrad G 52	Conrad G 53	Conrad G 54	Conrad G 55	Conrad G 56	Conrad G 57	Emporium I 19	Emporium I 20	Emporium I 21	Emporium I 22
LATITUDE	27,825 ft. S 41°35'	21,075 ft. S 41°35'	24,175 ft. S 41°35'	22,450 ft. S 41°35'	22,725 ft. S 41°35'	23,875 ft. S 41°35'	28,200 ft. S 41°35'	24,700 ft. S 41°35'	26,050 ft. S 41°35'	27,400 ft. S 41°35'
LONGITUDE	15,775 ft. W 77°55'	6,150 ft. W 77°55'	13,300 ft. W 77°55'	11,500 ft. W 77°55'	16,050 ft. W 77°55'	16,475 ft. W 77°55'	7,150 ft. W 78°00'	2,275 ft. W 78°00'	3,950 ft. W 78°00'	5,200 ft. W 78°00'
DATE COMPLETED	5-29-68	8-21-68	6-15-68	7-15-68	7-26-68	8-28-68	8-21-68	8-28-68	8-7-68	9-4-68
ELEVATION	1973 KB	2117 KB	2147 KB	1984 KB	1845 KB	2101 KB	1793 KB	1610 KB	1779 KB	1509 KB
TULLY	5464-5534	5678-5746	5685-5752	5550-5618	5380-5449	5603-5675	5356-5429	5148-5215	5309-5378	5043-5113
ONONDAGA LIMESTONE CHERT	6158-6173	6445-6458	6395-6409	6260-6272	6094-6112	6307-6322	6070-6088	5840-5858	6017-6034	5759-5778
ORISKANY	6173-6206	6458-6485	6409-6438	6272-6299	6112-6141	6322-6347	6088-6118	5858-5890	6034-6068	5778-5809
HELDERBERG	6206-	6485-	6438-	6299-	6141-	6347-	6118-	5890-	6068-	5809-
SALINA										
GUELPH-LOCKPORT										
CLINTON										
MEDINA										
QUEENSTON										
TOTAL DEPTH	6250	6529	6483	6350	6184	6397	6159	5932	6106	5847
DEEPEST FORMATION REACHED	Helderberg	Helderberg	Helderberg	Helderberg	Helderberg	Helderberg	Helderberg	Helderberg	Helderberg	Helderberg
RESULT	East Fork-Wharton Gas Storage	East Fork-Wharton Gas Storage	East Fork-Wharton Gas Storage	East Fork-Wharton Gas Storage	East Fork-Wharton Gas Storage	East Fork-Wharton Gas Storage	East Fork-Wharton Gas Storage	East Fork-Wharton Gas Storage	East Fork-Wharton Gas Storage	East Fork-Wharton Gas Storage

MAP NUMBER	41	34	42							
COUNTY Permit Number	Somerset 38	Westmoreland 532	Wyoming 6							
NAME OF WELL	Thomas D. Barron 1	George F. Dible 1	Farr 1							
OPERATOR	Peoples Natural Gas Co., et.al.	Fox, Coen, & Sloan	Pennzoil United, Inc.							
TOWNSHIP	Jefferson	Franklin	Monroe							
QUADRANGLE	Somerset H 32	Greensburg D 8	Harvey Lake C 2							
LATITUDE	10,500 ft. S 40°05'	4,450 ft. S 40°25'	14,500 ft. S 41°30'							
LONGITUDE	23,000 ft. W 79°05'	9,100 ft. W 79°40'	7,600 ft. W 76°00'							
DATE COMPLETED	3-15-69	9-12-68	10-1-69							
ELEVATION	2045 KB	1073	846 KB							
TULLY		*7224-7385	*5040-5095? *5290- ?							
ONONDAGA LIMESTONE	*8499-8520	*7883-7899								
ONONDAGA CHERT	*8520-8641	*7899-8115								
ORISKANY	*8641-8733	*8115-8154								
HELDERBERG	*8733-	*8154-								
SALINA										
GUELPH-LOCKPORT										
CLINTON										
MEDINA										
QUEENSTON										
TOTAL DEPTH	8781	8781	5385							
DEEPEST FORMATION REACHED	Helderberg	Helderberg	Middle Devonian							
RESULT	NSG nat. 850 Mcf AF, 8535-8781 Abandoned	Dry in Oriskany, Completed as "Benson" (Upper Devonian) discovery Lyons Run Pool	No shows Abandoned							

PART IV. TEN YEAR REVIEW AND FORECAST

SUMMARY REVIEW AND FORECAST

Pennsylvania: Conservative Exploitation of the Known and Cautious Probing of the Unknown

The 1960's in Pennsylvania saw an increased number of oil wells drilled but a decline in the exploration and development of natural gas.

Table 19 shows a 24 to 30 percent decline in the average number of shallow gas wells and deep wells reported per year. In Pennsylvania, wells are categorized "deep" or "shallow" on the basis of stratigraphy rather than depth. Wells reaching the Middle Devonian Tully limestone or deeper are called deep wells and those stopping in the Upper Devonian strata are shallow wells.

Table 19. Average number of gas wells reported per year.

	1950's	*1960's*
Average number of shallow gas wells per year	238	180
Average number of deep wells per year	139	98

The concentration of wells drilled for shallow gas in the Upper Devonian sandstones moved from Armstrong County in the 1950's to Indiana County in the 1960's. Developments during the past ten years mainly are in filling of the eastern edge of the established gas belt and a gradual eastward extension of the producing area by outstep drilling. A total of over seven trillion cubic feet of gas has been produced from the shallow gas sands since records have been kept (Lytle and others, in press).

Discovery and major development of most of the deep Oriskany (Lower Devonian) gas fields associated with fault traps on the prominent anticlines of the eastern Appalachian Plateau occurred during the 1950's. These fields extend from southern Potter County southwest to Fayette County. The two major fields of the trend are the Leidy field (see Figure 13), discovered in 1950, and the Punxsutawney-Driftwood field, whose various pools were discovered throughout that decade. Exploration in the 1960's was more extensive but less venturesome than in the 50's and discoveries of new fields were essentially confined to the known northeast-southwest trends. The most significant discoveries of the past 10 years are the Elk Run Pool and Rager Mountain Field. Figure 13 shows the fields that were discovered in the 1950's and those which were

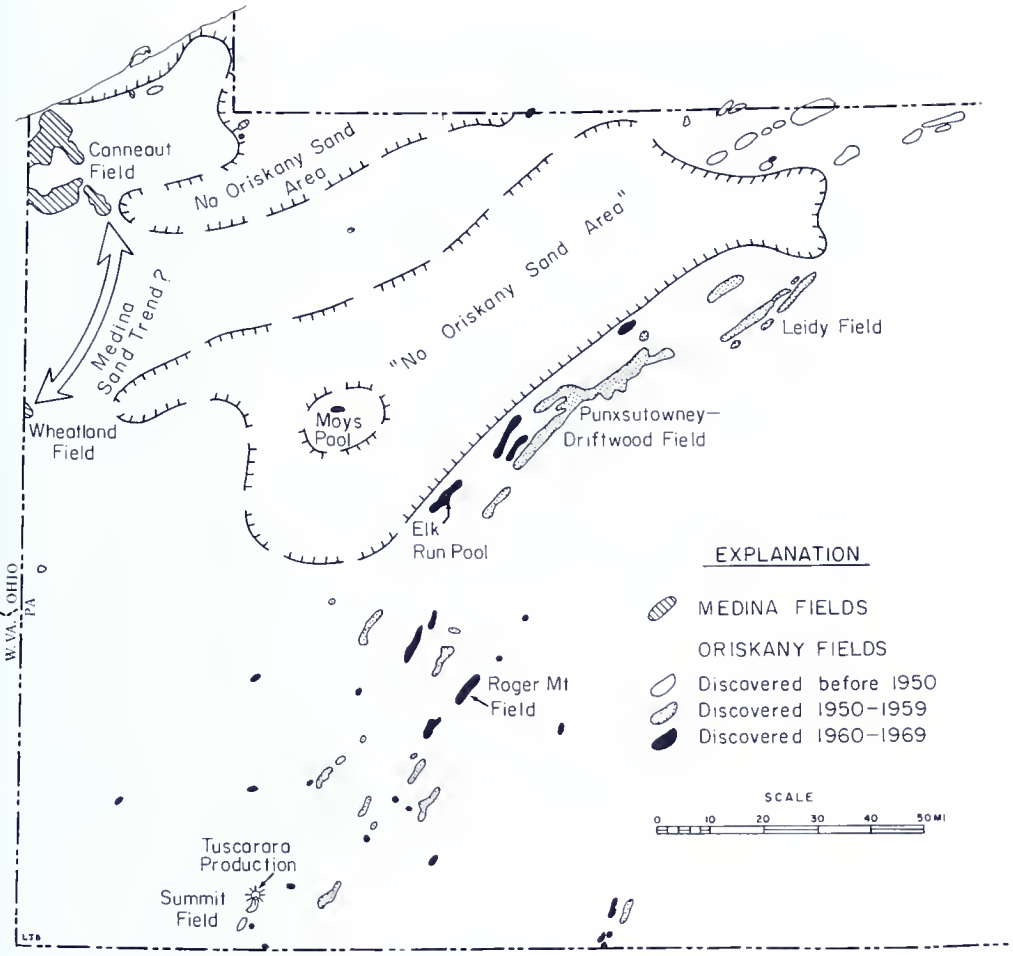


Figure 13. Oriskany and Medina (Deep well) fields of Pennsylvania.

found in the 60's. In Pennsylvania, approximately one trillion cubic feet of gas has been produced from the Oriskany sandstone and the overlying Huntersville chert since the discovery of gas in these rocks in the 1930's (Lytle and others, in press).

The Lower Silurian Conneaut Field, which produces gas from the Medina sandstones, was developed in the 60's after its discovery in the late 1950's. Between 1964 and 1967 over half the deep gas wells that were drilled in Pennsylvania were located in the Conneaut Field of Crawford and Erie Counties in the northwestern part of the State (Figure 13). The Medina sandstones have contributed 0.025 trillion cubic feet to Pennsylvania's production (Lytle and others, in press).

Very deep exploration in the Cambrian and Lower Ordovician dolomites and sandstones increased from 11 wells drilled in the 50's to 30 wells drilled in the 60's. Two of these 30 wells produced a little gas in Crawford County from Cambrian dolomites and sandstones which are

truncated by the regionally extensive unconformity lying at the base of the Middle Ordovician strata (Wagner, 1966 b).

The advent of air rotary drilling and well completion by hydraulic fracturing in the 1950's, gave the industry in the 60's a means of developing oil and gas fields which in previous decades would have been either abandoned or never discovered. This is particularly the case in the Oriskany-Hunterville fields of southern Pennsylvania, where the Huntersville chert at great depth yields commercial amounts of gas only after fracing (Lytle, 1965). Fracing, introduced into the oil belt in 1961, caused a boom in oil well drilling in the 60's resulting in a nine fold increase over the 50's (see Table 20).

Table 20. Average number of oil wells drilled per year.

	1950's	*1960's*
Average number of oil wells drilled per year	28	246

The concept of the "Appalachian Basin", an asymmetric synclinorium with a steep eastern flank approximately coincident with the eastern edge of the Appalachian Plateau, began to disintegrate in the late 1950's and additional drilling in the Valley and Ridge Province during the 60's completed the demise of the basin as a structural feature. The discovery of subsurface overthrusts in the Valley and Ridge Province east of the Plateau indicate that the Cambrian to Silurian rocks at the surface are not in place, but are shoved in from the east. Below the overthrusts at great depths lie the inplace rocks which are in continuity with the subsurface Cambrian to Silurian strata of the Plateau. These in-place strata lie at greater depths than the corresponding strata under the Plateau, thus showing that the eastern limb of the Appalachian Basin does not exist at the edge of the Plateau. These ideas were documented in a classic paper by Gwinn (1964).

Surrounding States: New Discoveries and Development

Despite the sluggishness of drilling activity in Pennsylvania in the 1960's, the rest of the Appalachian area was far from idle. Activity in West Virginia included discovery and development of gas in the Williamsport sandstone (Upper Silurian) and the Tuscarora sandstone (Lower Silurian). Central Ohio boomed with discovery of oil in Cambrian dolomites and by 1968 and 1969, drilling in Columbiana County near the Pennsylvania border, resulted in important Cambrian to Lower Ordovician gas discoveries. In New York State during the past several

years, two fields have been developed, one in an Onondaga (Middle Devonian) reef and the other in the Trenton (Middle Ordovician) limestones.

Significantly all of these productive strata also occur in Pennsylvania yet, with the exception of the Onondaga interval, only a handful of wells have tested these strata in the Commonwealth. These few tests have so far found one Tuscarora producing well and two Cambrian producing wells.

Evaluation of New Prospective Objectives and Areas Required

The outlook for the next few years is for the continued development of the shallow gas fields of eastern Indiana County and adjacent Jefferson County. Exploration will also extend into southern Westmoreland County and Fayette County. Deep gas production in the anticlinal Oriskany-Huntersville trend and in the Medina of northwestern Pennsylvania will slowly decline.

For the late 1970's and the future the emphasis must be placed on the deeper rocks: principally Williamsport and Tuscarora sandstone production in southern Pennsylvania, the Lockport dolomite throughout the western Plateaus Province, and the Cambrian to Ordovician rocks that underlie the whole Plateaus Province.

THE PAST DECADE AND FUTURE DEVELOPMENT IN KNOWN AREAS AND PAYS

Oil Developments

Figure 14 shows the areas where drilling for oil was concentrated during the 60's; these areas accounted for the nine-fold drilling increase over the 1950's. The increase is due mainly to the successful fracturing of oil wells, but may, in part, also be due to better methods of accumulating drilling statistics. Significantly, the drilling splurge was not from wildcat wells, but from within the established oil belt, in areas of former marginal production. Almost all the oil comes from the Upper Devonian sandstones of zones B and D. The one exception is 142,000 barrels of Corning grade oil produced from 121 Medina sandstone wells of Crawford and Erie Counties.

Since the late 1920's in Pennsylvania, the main source of oil has been from secondary recovery operations by waterflooding, mainly in the Bradford Field. Figure 6 shows that the State's oil production closely parallels the productive history of the Bradford Field. During the 60's operators in the Bradford Field ran out of acreage to waterflood; the number of wells drilled for waterflooding declined from over 600 in

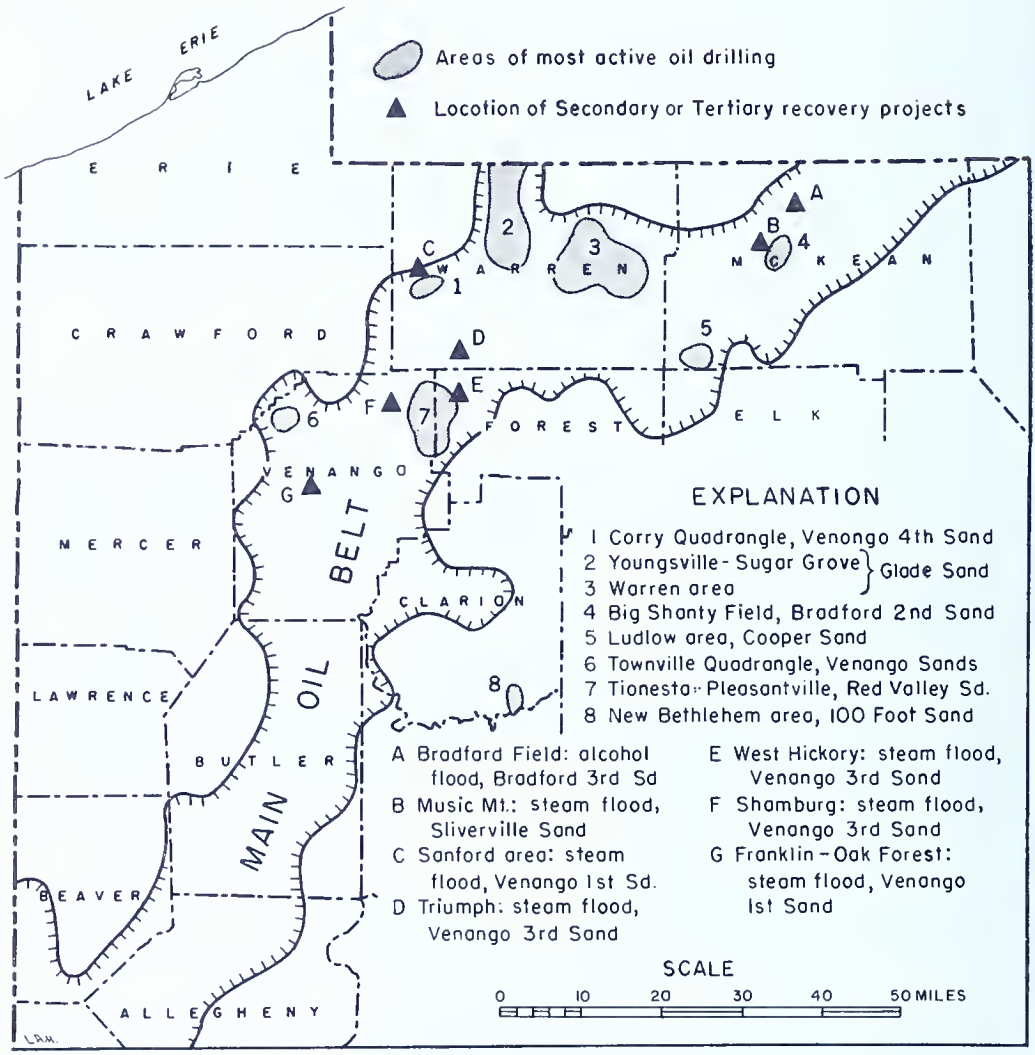


Figure 14. Areas of oil activity 1960-1969.

1961 to less than 60 in 1967. As a consequence, the oil production of the State has dropped approximately one-third in the past decade, from six million barrels in 1960 to about four million in 1968. Unfortunately, for the future of the oil industry in the State, the increase of primary oil obtained from the fracing of marginal oil fields was not sufficient to offset the rapid decline of secondary oil.

Numerous secondary and tertiary oil recovery projects were attempted during the 60's to recover from the low permeability Upper Devonian sandstones the remaining oil, estimated at 60 to 65 percent of the original oil in place. Figure 14 shows the location of the projects and the name of the sands (See Lytle, 1966; Sterner and Campbell, 1968). Most of the projects have been discontinued and for some, the data are not avail-

able, which probably indicates unsuccessful results. The latest attempt at tertiary recovery is the highly publicized Maraflood Process in the Bradford Third sandstone in the Bradford Field, where a micellar solution has been injected into the sand and is driven by a mobility buffer which will be followed by ordinary water drive. Results are not yet forthcoming.

Results to date do not offer great encouragement for future oil prospects in Pennsylvania. Almost all exploration has been confined to the oil belt whose boundaries were determined at the turn of the century. Even moderate success with tertiary recovery in northern Pennsylvania and secondary recovery in the southern part will merely delay the eventual decline of the State's oil industry. Wildcatting is hardly ever attempted; only a few companies in recent years have looked, unsuccessfully thus far, for *new* reserves in a few areas of north-central and northeastern Pennsylvania. It appears that only a major breakthrough in technology or application of secondary or tertiary recovery will rejuvenate Pennsylvania's historic oil patch. Successful wildcatting outside the oil belt may also delay the decline, or possibly outline areas for some limited exploitation expansion.

Natural Gas

Statistics for natural gas are graphed on Figure 8. During the 60's the net production of gas remained steady at about 90 billion cubic feet per year while the estimated proved recoverable reserves increased. The estimated proved recoverable reserves for the 1950's average about 520 billion cubic feet per year whereas the 60's average about 780 billion cubic feet per year, an increase of 260 billion cubic feet per year. This increase in reserve offers an interesting contrast to the net production curve which has slowly declined since 1954. One interpretation is that Pennsylvania is producing at less than capacity.

Table 21 shows subdivision of the net natural gas production into deep and shallow categories for 1960 to 1969.

Table 21. Deep and shallow gas production, 1960-69.

Production in BCF	*1960*	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	*1967*	*1968*	*1969*
Deep Gas	69.6	41.6	41.1	29.4	23.6	25.3	19.7	41.5	25.9	17.8
Shallow Gas	50.1	56.7	46.2	62.9	61.7	57.4	71.7	48.5	62.1	61.3
Total Gas	119.7	98.3	87.3	92.3	85.3	82.7	91.4	90.0	88.0	79.1

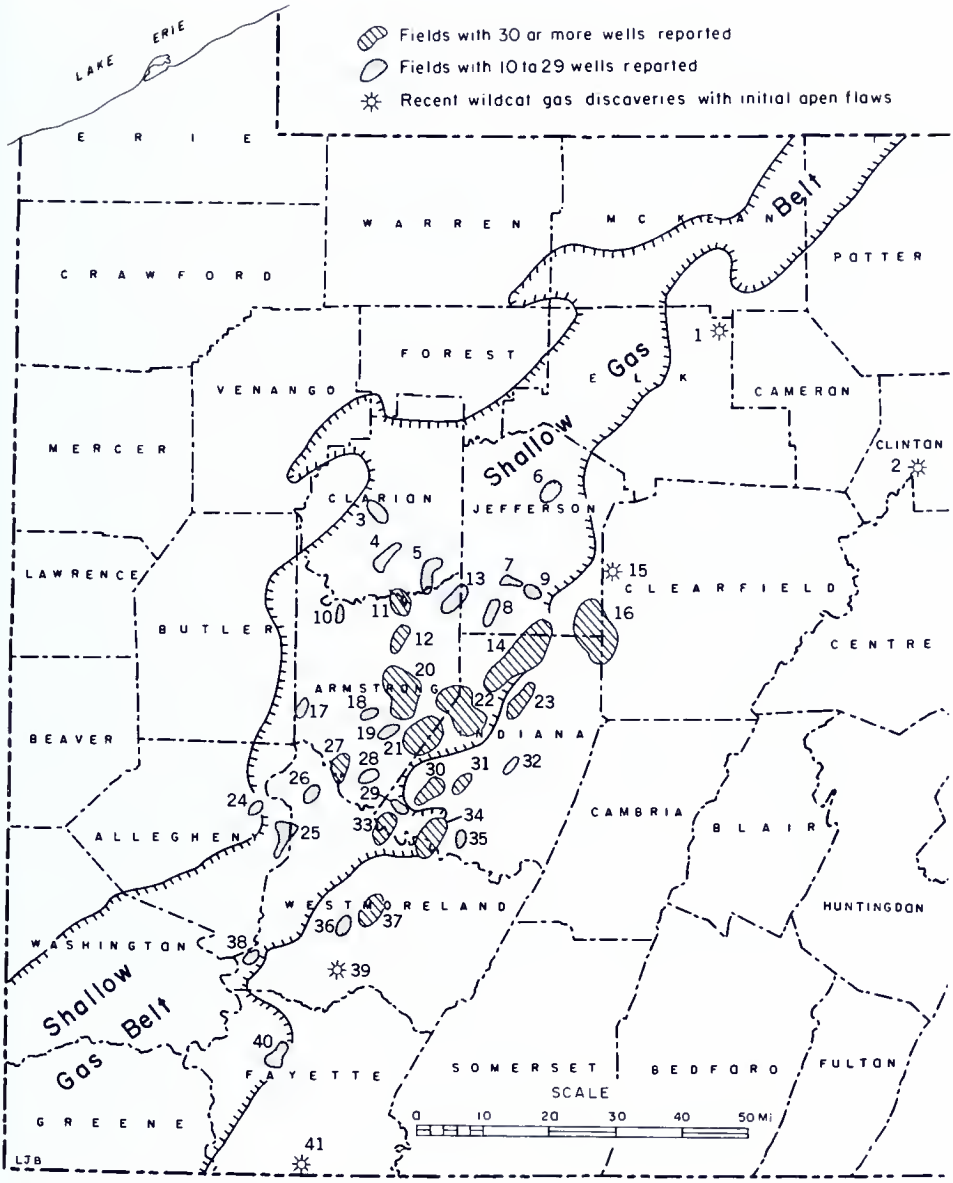
During the decade deep gas production (Oriskany-Huntersville, Medina) was stabilized between 20 and 30 BCF per year except in the early 60's when large volumes were produced from the Punxsutawney-Driftwood Field and in 1967 when 23 of the 41.5 BCF produced came from the Elk Run Pool. The table shows that when deep gas production is high, shallow gas production dwindles, as in 1967, and conversely, when deep gas production lags, as in 1966, a large supply of shallow gas is the compensating factor. An interpretation of this variable interrelationship between deep and shallow gas production is that shallow gas is a readily available supply to be tapped when the deep gas supply wanes or the supply of pipeline gas from out-of-state is either interrupted or consumed at rates greater than anticipated. The increase of proved recoverable native reserves during the past decade probably indicates that shallow gas reserves are increasing more rapidly than withdrawal rates.

Consumption of natural gas in Pennsylvania during the 60's has increased from about 520 BCF per year to over 700 BCF (see Figure 9). More than 80 percent of the amount consumed is imported via pipeline from the Gulf Coast area.

Shallow Gas

Figure 15 shows the main areas of shallow gas activity from 1960-1969. Most of the activity occurred in western Indiana and southern Jefferson County at the eastern edge of the established shallow gas belt where outstepping wells are filling in between known productive areas and moving the boundary of the gas belt eastward. The two major fields in these categories are the Big Run-Johnsonburg-Bell-Reed-Deemer Field (No. 16 on map) and the Marchand-Juneau-Richmond-Rossmoyne Field (No. 14 on map). Considerable activity also took place within the gas belt, particularly in Armstrong County and northern Westmoreland County, where old wells were re-entered and fraced, or new wells were drilled and fraced, in existing, producing fields.

The main producing 1,000 foot interval is designated Upper Devonian zone B and contains numerous sandstones locally called (from top to bottom) Warren, Speechley, Balltown, Sheffield, and Bradford. In several instances, such as in the West Newton Field (No. 38) and the Sherrick Run Pool (No. 39), Lower Mississippian sands (Murrysville) and sands of Upper Devonian zone D (Hundred Foot) are also productive.



1 Straight Creek–0.3 MMcf
2 Keating–0.6 MMcf
3 Shamburg
4 Bittenbender
5 Shannondale–New Bethlehem
6 Warsaw
7 Markton
8 North Paint
9 Oliveburg
10 Madison
11 Climax–Mahaning Furnace
12 Gaheenville
13 New Solem
14 Morchand–Juneau–Richmand–Rossmayne
15 Salem–1.4 MMcf
16 Big Run–Johnsonburg–Bell–Reed–Deemer
17 Slate Lick
18 Rockville
19 Shellhammer
20 Yatesboro–Cawon–shannack–Whitesburg
21 Plum Creek
22 Creekside–Say–Willet–Atwood
23 Marion Center
24 Milltown
25 Plum–Murrysville
26 Pine Run
27 Vandergrift–Apalta
28 Roaring Run
29 Clarksburg
30 Jacksanville–Watts
31 Crete
32 Cherry Hill
33 Saltsburg
34 Blairsville
35 Blacklick
36 Latrobe–Armburst
37 Latrobe
38 West Newton
39 Sherrick Run–6 MMcf
40 Waltersburg
41 Sandy Creek–2 MMcf

Figure 15. Shallow gas activity 1960-1969.

From 1961 to 1969 the number of shallow gas wells drilled per year gradually increased and the average initial open flow potential also increased from less than 600 Mcf per day in the early 1960's to over 1,000 Mcf per day in the middle and late 1960's. Although fracing was a common practice throughout the decade, the greater open flow potential was probably the result of the new fields discovered in Northern Indiana and southern Jefferson County combined with multiple zone fracing and commingling of gas from various zones.

If declining oil represents Pennsylvania's past, then increasing shallow gas represents the future of the Commonwealth. During the 1970's gas fields will probably cover Indiana, southern Jefferson and southwestern Clearfield Counties as production continues to spread eastward to the place where the near-shore sediments of zone B are replaced by more continental sediments such as the Catskill redbeds. Accompanying this eastward development will be expansion to the southwest along the stratigraphic trend of the zone B sands into southern Westmoreland County and Fayette County. This trend has already begun with the discovery of the Sandy Creek Field (No. 41) along the State border in Fayette County. Also of interest is the activity in the old Waltersburg Field (No. 40) and a new pool discovery, the Sherrick Run Pool (No. 39, see Highlights section) in southern Westmoreland County.

Trending northeast from the area of present development, the zone B sands are present in northern Jefferson and southern Elk Counties. Although production has been obtained from the general area in the past few years (Straight Creek Field, No. 1; Keating Field, No. 2; Salem Pool, No. 15), development may be slow because of unavailability of leases and considerable forest acreage held by the State.

The long term future of shallow gas is dependent on finding new reserves not associated with extension of the present trend. The possibility exists that deeper Upper Devonian sands lying stratigraphically lower than zone B may occur in Somerset and southern Cambria Counties. Another locality worthy of exploration is the area of the thick delta-front Upper Devonian sandstones of northeastern Pennsylvania (Glaeser, 1970), which is not present in the western part of the State, and from which shows of gas and water have been reported.

Net production of shallow gas will probably increase during the next few years. As pipeline gas becomes less plentiful, local gas utility companies, which have heretofore obtained all their supply from the pipelines, probably will be forced into exploration for gas within the State. Those utilities which have exploration operations in Pennsylvania will most likely increase their activity. For example, Peoples Natural Gas Company announced that in 1970 it expects "to drill 52 wells—its greatest drilling venture in 20 years."

Deep Gas

Oriskany Sandstone and Huntersville Chert

Approximately 300 BCF of gas were produced from the combined Oriskany-Huntersville reservoir during the past decade, which is about 30 percent of the total accumulative production. In contrast, about 50 percent of the total accumulative production was obtained from this reservoir in the 1950's. As almost all of this volume is from the eastern Plateau, it indicates that the anticlinal belt reached its productive peak in the 50's and began to decline in the 60's.

During the past 10 years the two main discoveries in terms of production were the Rager Mountain Field and the Elk Run Pool (Figure 13). The Rager Mountain Field extended the Oriskany-Huntersville trend along the Laurel Hill anticline into Cambria County and produced 8.2 BCF from fault bounded reservoirs of predominantly fracture porosity (Heyman in Kelley and others, 1969). The Elk Run Pool in Jefferson County is significant for its production of 36.2 BCF from the Oriskany sandstone and also because it is a stratigraphic trap, having up-dip loss of porosity and a down-dip gas-water contact. Located on the southeastern flank of the Elk Run anticline, the pool has a mean intergranular porosity of almost eight percent and original estimated reserves of 47 BCF (Heyman, 1969).

In spite of the declining statistics for the established Oriskany-Huntersville trend, the productive future of the Oriskany sandstone is not limited because much of the western Plateau holds promise of production. The Elk Run Pool (Figure 13), situated at the pinch out of the Oriskany on the southeastern side of the so-called "No Sand Area," is a strong inducement for further exploration to define the southern edge of the "No Sand Area" in Indiana, Armstrong, and Butler Counties in attempts to find new "Elk Run" stratigraphic pinch outs. The Mays Pool (Figure 13) discovered in 1963 with cumulative production of over 6 MMCF and salt water, lies within the "No Sand Area" and suggests that other more productive fields may be present where the sand is preserved in structural lows within the former "No Sand Area." In 1966 three small Oriskany pools were discovered in Erie County. The manner of entrapment appears to be a combination of stratigraphy and structure, the structural part being related to solution of the underlying Upper Silurian (Salina) salt (Kelley and McGlade, 1969). Western Pennsylvania may become a region of structural Oriskany traps if salt solution is extensive throughout the western part of the Plateau. An interpretation of an article by Summerson and Swann (1970) is that the Oriskany of the western Plateau is a younger sandstone than the true Oriskany of the eastern Plateau anticlinal belt. The younger, western sandstone is be-

lieved to have had a northwestern source whereas the true Oriskany was derived from the southeast. If this hypothesis is correct, then the younger "Oriskany" may form stratigraphic traps where it disappears against the northwestern edge of the now no longer extensive "No Sand Area" in Warren, Forest, or Venango Counties.

Medina Sandstones

From 1960-1969, 439 wells were drilled to the Lower Silurian Medina sandstones in Erie and Crawford Counties. This represents about 15 percent of all the deep wells drilled in Pennsylvania. Over half of these wells were drilled between 1964 and 1967.

The Medina sandstone trend in Erie and Crawford Counties (Figure 13) is just a small segment of the "Clinton" belt which extends north-south through east-central Ohio and then bends northeastward into northwestern Pennsylvania and then into western New York. Production comes from very fine to medium grained sandstones deposited in a deltaic environment. The thickest shale-free sands which possess porosities in excess of 10 percent are the most productive (Kelley in Lytle and others, 1966; Kelley and McGlade, 1969). Structure apparently plays little, if any, role in the entrapment of the gas.

Medina production appears to be limited in westernmost Pennsylvania to the belt of deltaic and near-shore beach sands which was deposited west of the thicker and sandier Tuscarora sandstone facies. With the discovery in 1963 of the small Wheatland Field in western Mercer County (Figure 13), the area of maximum development of sands may extend from heavily drilled Erie and northern Crawford Counties into relatively untested southern Crawford and northern Mercer Counties (Kelley and McGlade 1969, Fig. 5) and also into Lawrence County (Knight, 1969, Figs. 14 and 15).

FUTURE DEEP PROSPECTS

Surrounding New Discoveries Presage Delayed Expansion into Pennsylvania

About 25 years ago (1945) the prospects of deep production in Pennsylvania were not bright. Surrounding states were finding gas in the Oriskany and Medina sandstones, but in Pennsylvania the Medina did not produce and the known productive boundaries of the Oriskany ended just a short distance into the State. The well established Medina gas trend through Ohio, Ontario, and western New York apparently bypassed Pennsylvania. The Oriskany sandstone had become an important source of gas in south-central New York and particularly in south-

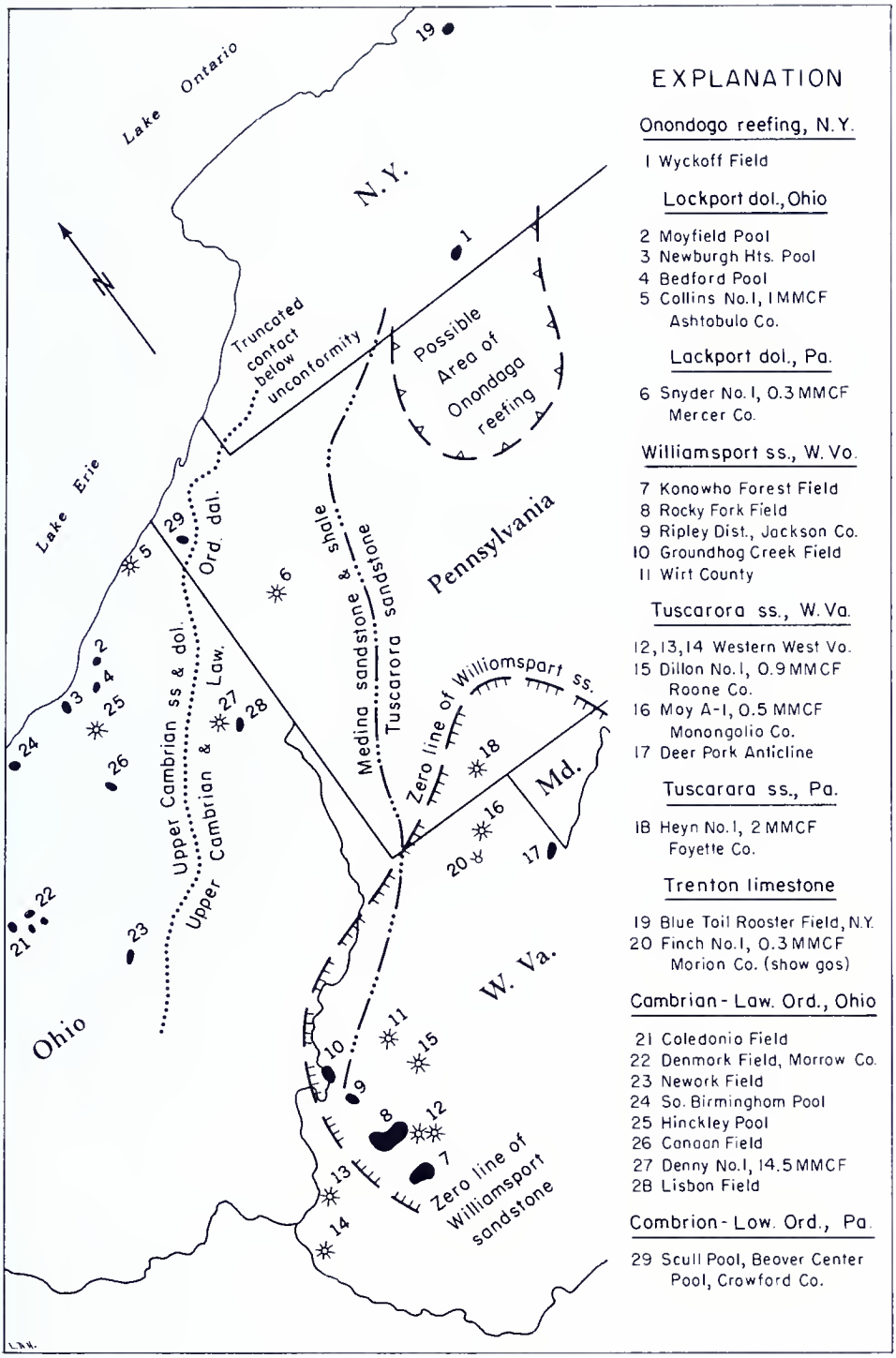


Figure 16. Selected deep gas and oil fields of northern Appalachian area (excluding Oriskany and Medina fields).

western West Virginia; small Oriskany fields had been discovered in northeastern Ohio, yet Pennsylvania could claim only the fields of Potter and Tioga Counties which were discovered in the 30's and the Summit Field of Fayette County. Thus, a 1945 map of deep production in the northern Appalachian area showed almost a blank for Pennsylvania, whereas many prolific oil and gas fields were located in the surrounding states.

A situation similar to 1945 exists today in Pennsylvania. Figure 16 shows some of the deep producing fields of the northern Appalachian area excluding Oriskany and Medina fields. The stratigraphic units from which these fields produce are widely distributed in Pennsylvania, but as yet, are either not productive or are just barely productive. The units are the Onondaga reefs of New York, the Lockport of Ohio, the Williamsport and Tuscarora of West Virginia, the Trenton of New York, and the Cambria to Lower Ordovician strata of Ohio. Comments on each of these units are given below.

Onondaga Reefing

In 1967, a subsurface Onondaga limestone reef was discovered in Jasper Township, Steuben County, New York (No. 1, Fig. 16). Three wells produce gas from the reef, the largest initial open flow being 10½ MMcfpd (Kreidler et al., 1968). Reefing occurs in the central area of western New York where the Onondaga regionally is less than 50 feet thick. East and west of the central area, the limestone thickens to over 150 feet (Oliver, 1954; Jones and Cate, 1957). The reef may have grown because it was located on a platform lying between subsiding areas. This area of Onondaga thinning extends into north-central Pennsylvania and other reefs may possibly exist on this platform area which is outlined on Figure 16. The reefing may also be associated with structural trends, particularly faulting.

Lockport Dolomite

Many years ago, gas was obtained from porous zones within the Middle Silurian Lockport Dolomite of northeastern Ohio east of Cleveland (Nos. 2, 3, 4). Recently, interest in the Lockport has been renewed with the discovery of 1 MMcfgpd from a well in Ashtabula County, Ohio (No. 5, Fig. 16) and with finding of the first small Lockport gas pool in Pennsylvania in 1966 (No. 6, Fig. 16). Numerous wells drilled to the Medina sandstones in northwestern Pennsylvania have found gas shows, some significant, and salt water in the Lockport.

The Lockport dolomite underlies the western part of the Pennsylvania plateau and to the east changes into limestone and shale of the McKenzie Formation which crops out in the Valley and Ridge Province. It has been hypothesized that reefs in the Lockport acted as the framework for development of the overlying Salina Salt Basin (Alling and Briggs, 1961). The presence of reefs in northwestern and southwestern Pennsylvania has also been proposed (Fergusson and Prather, 1968).

Williamsport Sandstone

Exploration for and development of the Williamsport sandstone (Upper Silurian) has dominated activity in West Virginia for the past three years (Woodfork in Lytle and others, 1969). Figure 16, (No. 7-11) shows the location of the fields (modified from Patchen, 1967) with respect to the postulated zero line of the Williamsport sandstone. Many of the fields (No. 7, 8) appear to be stratigraphic traps with up-dip porosity loss on plunging anticlines (Patchen, 1967). In 1969 development spread into Meigs County, Ohio with the discovery of the Groundhog Creek Field (No. 10). The trend of the Williamsport fields approximately parallels the zero line.

In all of southwestern Pennsylvania only three wells have reached the Williamsport interval and at least two of them recorded sandstone but no gas. On this basis the zero line of the Williamsport sandstone is extended into at least Fayette and Somerset Counties where future fields may lie entrapped on plunging anticlines in a manner similar to the fields of West Virginia.

Tuscarora Sandstone

The eastern facies of the Medina Group is the Tuscarora sandstone which is thicker and sandier than the Medina, and whose porosity, where the sandstone produces gas appears to be essentially fracture controlled. The approximate boundary between the Medina and the Tuscarora is shown on Figure 16. The three wells that penetrated the Williamsport sandstone in southwestern Pennsylvania also reached the Tuscarora. One of these wells (No. 18), discovered in 1964, produced 40 MMcf of 835 BTU gas in three months time before it was abandoned because of mechanical difficulties (Lytle and others, 1965).

Most of the Tuscarora drilling has so far been located in eastern West Virginia. Of particular interest was the discovery in 1963 to 1964, of a Tuscarora gas field just southwest of the Mountain Lake Park Oriskany Field (Figure 16, No. 17). Three wells were drilled in this pool of which one had an initial volume of 16 MMcfpd after perforation and another

recorded 22 MMcfpd naturally. The gas, however, had heating values of only 830 BTU (Patchen, 1969). In 1969 a Tuscarora well in Roane County, West Virginia found gas of commercial quality—0.9 MMcfpd of 989 BTU (Woodfork, in Lytle and others, 1969). Many of the Tuscarora discoveries are deeper well pools in shallower Oriskany fields.

Tuscarora drilling activity in West Virginia holds promise of future production in Pennsylvania, and southwestern Pennsylvania represents the most likely wildcat territory because the following multipay prospects can be evaluated: Upper Devonian, Oriskany-Huntersville, Lockport, and Williamsport and Tuscarora sandstones.

Trenton Limestone

The Middle Ordovician Trenton limestone was a source of oil or gas in New York and Ohio during the early 1900's. Interest in this unit has been rekindled in recent years with the discovery of gas in the Blue Tail Rooster Field in Cayuga County, New York (Figure 16, No. 19). The discovery well, drilled in 1966, had a reported 6.9 MMcfgpd and last year an outstepping well has an initial flow of 2.5 MMcfpd. In West Virginia, gas shows have occasionally been found in the Trenton; one of the more significant for Pennsylvania was from the Phillips Petroleum deep well in Marion County (No. 20) which in 1962 yielded 250 Mcf (Patchen, 1968).

Gas shows are common in the Middle Ordovician limestones of Pennsylvania and are probably derived from shale partings and fractures (Hartnagel, 1938). The upper part of the "Trenton" is composed of fossil fragments in a dark shale matrix deposited on a platform between deeper water black shale basins to the east and west (Wagner, 1966). Further exploration may find patches of the bioclastic limestone where much of the clayey matrix is missing, thus placing a porous reservoir rock adjacent to black shale source rocks.

Cambrian and Lower Ordovician Dolomites and Sandstones

Increased drilling to Cambrian and Lower Ordovician strata during the 1960's has resulted in increased knowledge of the regional distribution of these formations and the discovery of two one-well pools in Crawford County. Four thousand feet of Lower Ordovician dolomites present at outcrop in the Valley and Ridge Province are absent in the subsurface of northwestern Pennsylvania. The disappearance of this section is caused partly by truncation below a regional unconformity but mostly by onlap above it. As the unconformity is traced eastward from western Pennsylvania, older units progressively come in taking position

on top of the unconformity whereas increasingly younger units gradually appear below the unconformity. In the Valley and Ridge Province near the Pennsylvania State University, Centre County, the unconformity disappears and a complete stratigraphic section is present (Wagner, 1966a). The long-term future of petroleum production in the State may well depend on finding stratigraphic or combined traps associated with the onlapping Lower Ordovician dolomites and the truncated Lower Ordovician to Upper Cambrian dolomites and sandstones.

The two one-well gas pools in Crawford County (Figure 16, No. 29), discovered in 1964, are combined stratigraphic-structural traps in Upper Cambrian sandstone and dolomite. The traps occur where porous stratigraphic zones, truncated below the irregular surface of the unconformity, have been raised above the regional water level by a nearly vertical normal fault (Wagner, 1966b).

Less than 50 wells have reached Cambrian and Lower Ordovician strata in Pennsylvania. Most of the drilling activity in the 1960's which tested these units took place in Ohio, where oil found in buried erosional hills created a boom in Morrow County (Figure 16, No. 22). By 1968, deep Cambro-Ordovician exploration extended almost to the Pennsylvania border where the Denny No. 1 (No. 27) in Columbiana County had an initial potential of 14.5 MMcfgpd from dolomite below the unconformity. This discovery was followed in 1969 by new pool discoveries (Lisbon Field) of 10 MMcfgpd (Sell No. 1) and 5 MMcfgpd (Mrugala No. 1). (Both wells are represented by No. 28 of Figure 16). Production is from porous zones in Upper Cambrian and Lower Ordovician dolomites, a younger stratigraphic interval than the Upper Cambrian dolomites and sandstones which produced gas in Crawford County, Pennsylvania.

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